THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 17 FEBRUARY, 1938 Number 2

Edward Drummond Libbey

For story, see page 81

THIS FLUORIDE FLUX AND OPACIFIER MAKES A DIFFERENCE THAT YOU CAN *SEE*

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Volume 17 February, 1938 Number 2

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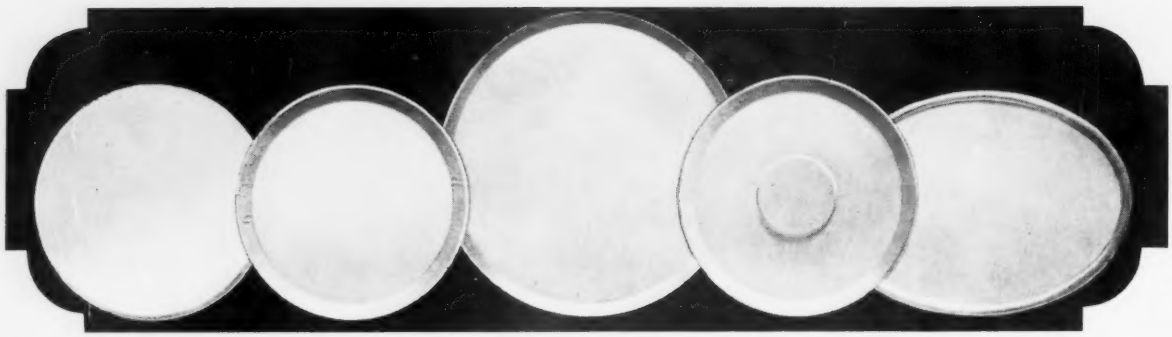

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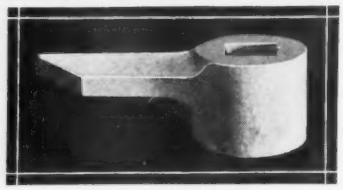

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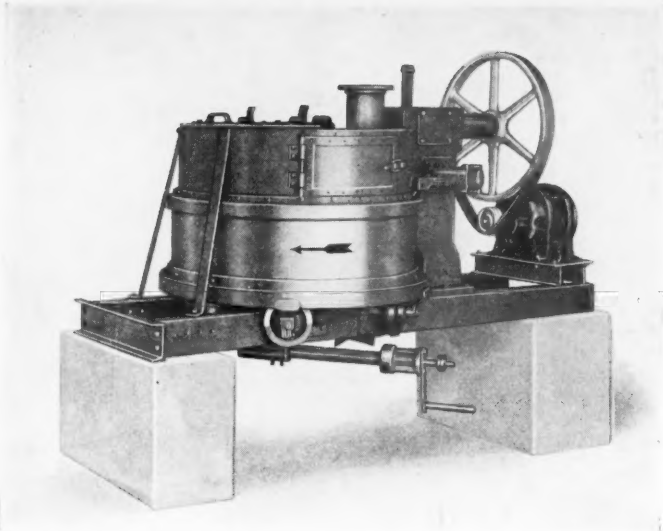

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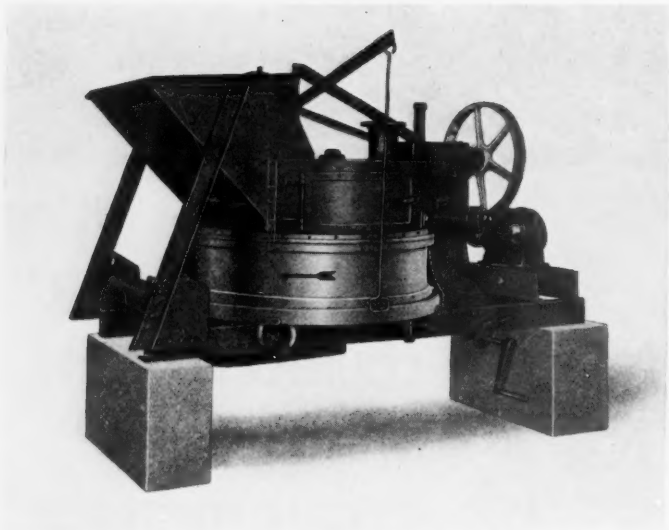

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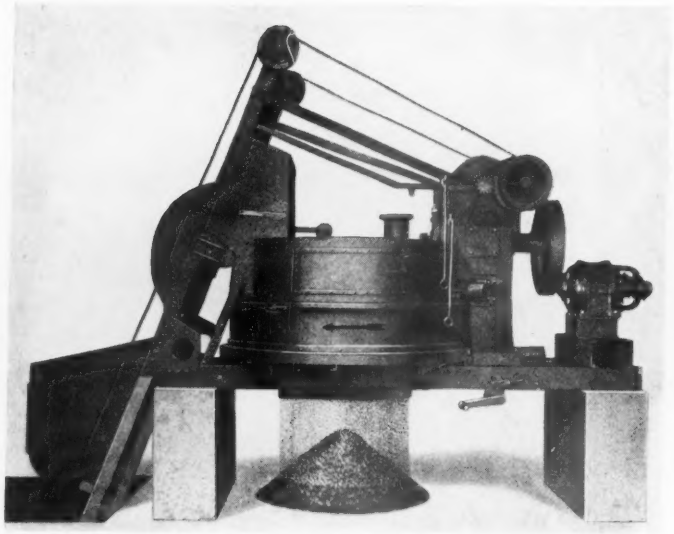

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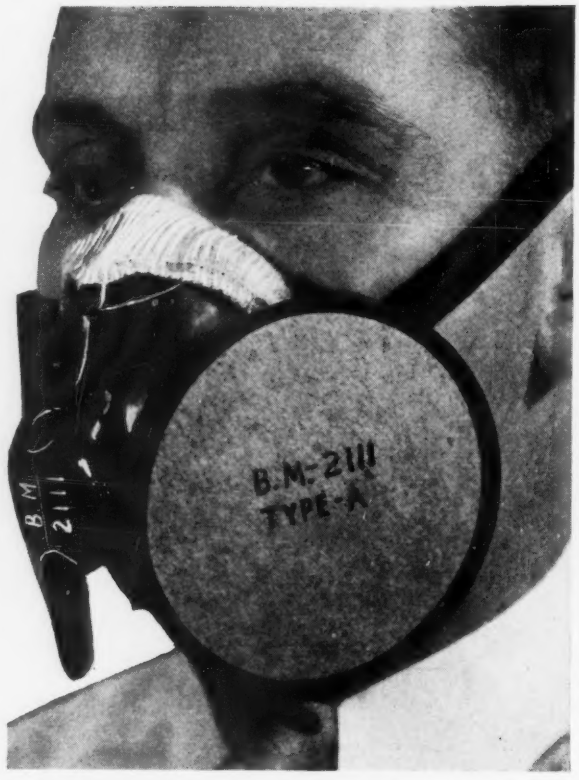

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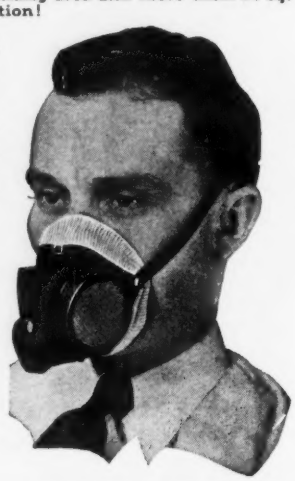

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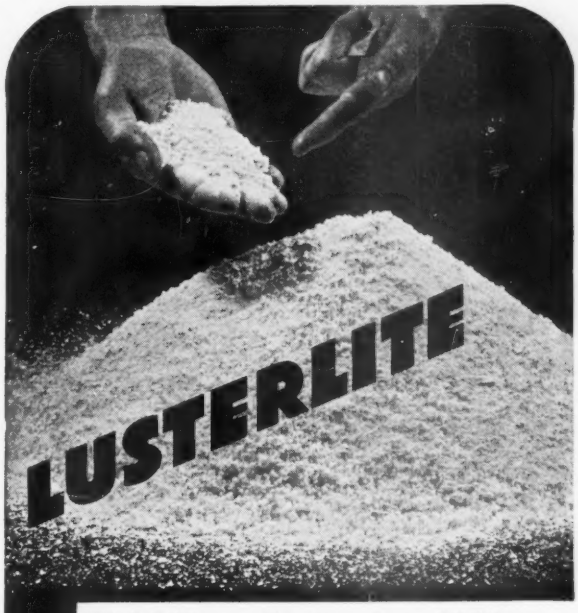

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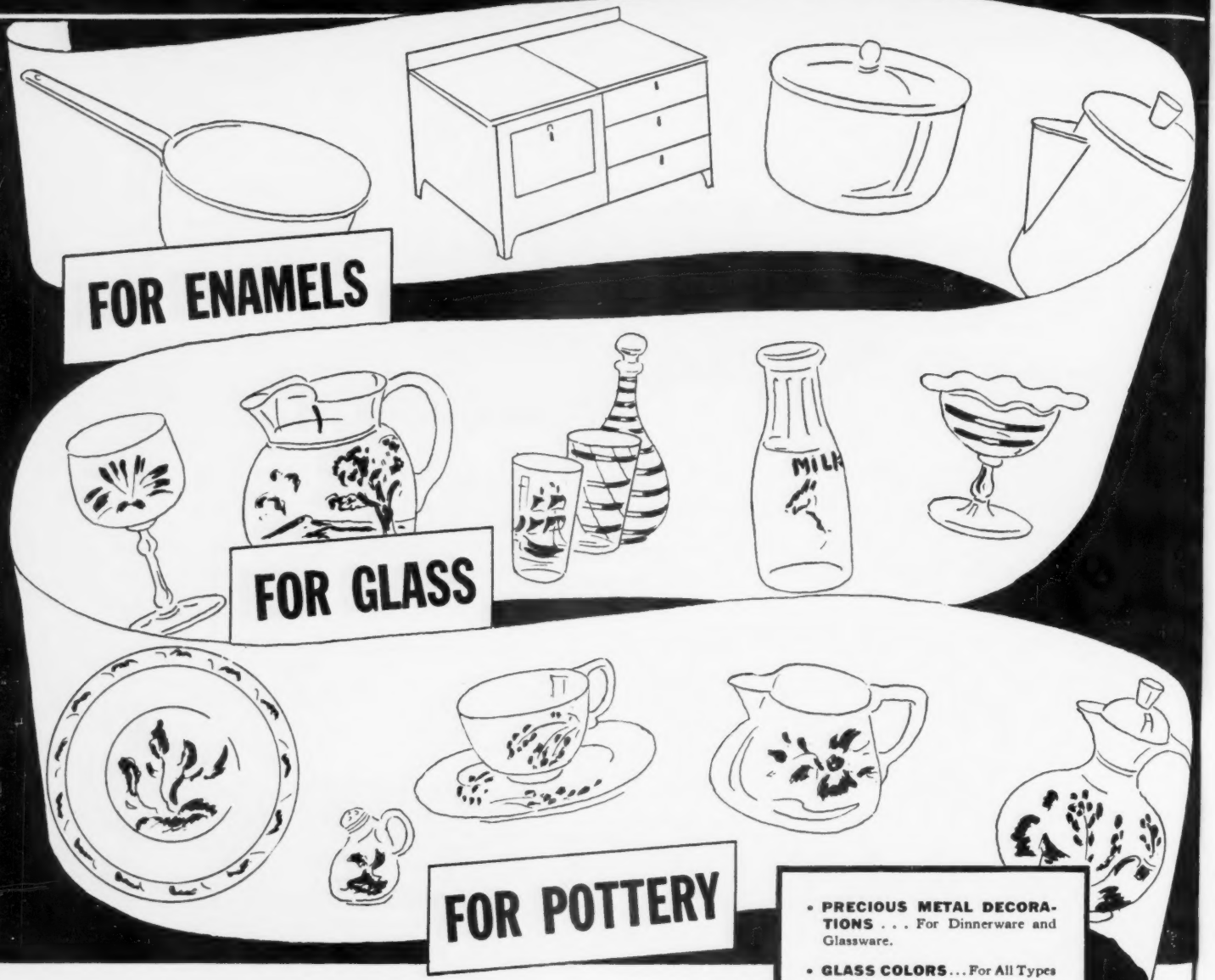

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Hammill & Gillespie, Inc.
The Hommel Co., O., Inc
Kentucky Clay Mining Co.
Paper Makers Importing Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Enamel)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
The Hommel Co., O., Inc.
Harshaw Chemical Co.
Kentucky Clay Mining Co.
Metal & Thermit Corp.
Paper Makers Importing Co.
The Porcelain Enamel & Mfg. Co.
Spinks Clay Co., H. C.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.
United Clay Mines Corp.

Clay (Fire)
Denver Fire Clay Co.
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Paper Makers Importing Co.
Pittsburgh Plate Glass Co.
Potters Supply Co.

Clay (German Vallendar)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Du Pont de Nemours, E. I., & Co., Inc , R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
The Hommel Co., O., Inc.
Harshaw Chemical Co
Kentucky Clay Mining Co.
The Porcelain Enamel & Mfg. Co.
The Vitro Mfg. Co.
United Clay Mines Corp.

Clay Miners
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Kentucky-Tennessee Clay Co.
Paper Makers Importing Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Potters)
Denver Fire Clay Co.
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Kentucky Clay Mining Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
Sant, Richard C.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Process Equipment)
Lancaster Iron Works, Inc.

Clay (Sagger)
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
The Hommel Co., O., Inc.
Kentucky Clay Mining Co.
Paper Makers Importing Co.
Pittsburgh Plate Glass Co.
Potters Supply Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Wad)
Kentucky Clay Mining Co.
Potters Supply Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Wall Tile)
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Kentucky Clay Mining Co.
Paper Makers Importing Co.
Sant, Richard C.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Cleaners
The Porcelain Enamel and Mfg. Co.

Cleaners, Chemical
Harshaw Chemical Co.

Clocks (Gauge Board)
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.

Cobalt Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Harshaw Chemical Co.
The Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cobalt Sulphate
Harshaw Chemical Co.

Colors
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Harshaw Chemical Co.
Pittsburgh Plate Glass Co.
The Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cones
The Edward Orton, Jr., Ceramic Foundation

Conveying Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.

Copper Oxide
Harshaw Chemical Co.

Corhart
Corhart Refractories Co.

Cornwall Stone (Imported)
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.

Crucibles (Filter, Melting, Ignition)
Carborundum Co.
Denver Fire Clay Co.
Norton Co.
Pittsburgh Plate Glass Co.
Potters Supply Co.

Crushers (Clay)
Lancaster Iron Works, Inc.

Cryolite (see Kryolith)
Ceramic Color & Chemical Mfg. Co
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Crystolon (Refractory Products)
Norton Co.

Cullet, Washing Plants, Incinerators, Crushers
Frazier-Simplex, Inc.

Decorating Supplies
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Harshaw Chemical Co.
Pittsburgh Plate Glass Co.
The Vitro Mfg. Co.

Disintegrators
Lancaster Iron Works, Inc.

Dryer (Pipe Rack)
Lancaster Iron Works, Inc.

Drying Machinery
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
Proctor & Schwartz, Inc.

Electrocast Refractories
Corhart Refractories Co.

Enameling Equipment (Complete)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Frazier-Simplex, Inc.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Enameling Furnaces
Carborundum Co.
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Electro Refractories & Alloys Corp.
The Hommel Co., O., Inc.
Lancaster Iron Works, Inc.
Norton Co.

Enameling Iron (Sheet)
American Rolling Mill Co.
Bethlehem Steel Co.

Enameling Muffles
Bethlehem Steel Co.
Carborundum Co. (*Carbofrax*)
Chicago Vitreous Enamel Product Co.
Electro Refractories & Alloys Corp.
Frazier-Simplex, Inc.
Norton Co. (*Alundum*)
Pittsburgh Plate Glass Co.

Enameling (Practical Service)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Enamels
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pittsburgh Plate Glass Co.
The Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Enamel Oxide
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Enamels (Porcelain)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Equipment (Porcelain Enameling)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
The DeVilbiss Co.
The Hommel Co., O., Inc.

Exhaust Systems
The DeVilbiss Co.

Feldspar
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
The Porcelain Enamel and Mfg. Co.
Sant, Richard C.
The Vitro Mfg. Co.

Fire Brick
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.

Fire Brick—Process Equipment
Lancaster Iron Works, Inc.

Fire Clay
Spinks Clay Co., H. C.

Flint
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
The Porcelain Enamel and Mfg. Co.

Flint Pebbles
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Floors (Non-Slip)
Norton Co.

Fluorspar
Harshaw Chemical Co.

French Flint
Consolidated Feldspar Corp.
Paper Makers Importing Co.

Frit
Allied Engineering Co.
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Frosting Mixtures
Harshaw Chemical Co.

Fuel Oil Systems and Control, Stokers
Bethlehem Steel Co.
Frazier-Simplex, Inc.

Furnaces
Allied Engineering Co.
Carborundum Co. (*Carboradiant*)
Chicago Vitreous Enamel Product Co.
Denver Fire Clay Co.
Frazier-Simplex, Inc.
The Hommel Co., O., Inc.

Glass Bending Ovens, Glass Decorating Machines
Frazier-Simplex, Inc.

Glass Equipment
Hartford-Empire Co.
Lancaster Iron Works, Inc.

Glass Melting Pots (Open and Covered)
Pittsburgh Plate Glass Co.

Glass Melting Tanks and Furnaces
Frazier-Simplex, Inc.
Pittsburgh Plate Glass Co.

Glass Thickness Gauge
Bausch & Lomb Optical Co.

Glaze and Body Spar
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
The Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Glazes and Enamels
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.

Goggles
Cover, H. S.
Willson Products, Inc.

Gold
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc. R. H. & Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Dept.

Gold Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Co.
Granulators
Lancaster Iron Works, Inc.
Grinding Wheels
Carborundum Co. (*Carborundum and Aloxite*)
Chicago Vitreous Enamel Product Co.
Norton Co. (*Alundum-Crystolon*)
Hearths
Carborundum Co. (*Carbofrax* heat treating)
Corhart Refractories Co.
Electro Refractories & Alloys Corp.
Norton Co. (*Crystolon*)
Hearths (Fused Al_2O_3, SiC)
Electro Refractories & Alloys Corp.
Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.
Hose (Air and Fluid)
The DeVilbiss Co.
Hydrofluoric Acid
Harshaw Chemical Co.
Iron Chromite
Harshaw Chemical Co.
Iron (Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.
Iron Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.
Kaolin
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Edgar Brothers Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
Sant, Richard C.
United Clay Mines Corp.
The Vitro Mfg. Co.
Kellog AA Refractories
Electro Refractories & Alloys Corp.
Kilns, China (Decorating)
Allied Engineering Co.
Denver Fire Clay Co.
Drakenfeld & Co., B. F.
Frazier-Simplex, Inc.
The Hommel Co., O., Inc.
Kiln Furniture (Silicon Carbide, Semi-Silicon Carbide)
Electro Refractories & Alloys Corp.
Kyanite
Celo Mines, Inc.
Kryolith (See Cryolite)
Pennsylvania Salt Mfg Co.
Laboratory Ware
Norton Co.
Lehr Tile (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Electro Refractories & Alloys Corp.
Lehrs
Frazier-Simplex Inc.
Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Lehr Loaders
Frazier-Simplex, Inc.
Linings (Furnace Refractory, Block Refractory Plate, Brick and Tile)
Carborundum Co.
Chicago Vitreous Enamel Product Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.
Pittsburgh Plate Glass Co.
The Vitro Mfg. Co.
Lithium Carbonate
Foote Mineral Co.
Lithium Minerals
Foote Mineral Co.
Magnesia (Fused)
Electro Refractories & Alloys Corp.
Norton Co.
Magnesia (Sintered, Calcined)
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Porcelain Enamel and Mfg. Co.
Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
Hammill & Gillespie, Inc.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.
Magnesite Calcined
Foote Mineral Co.
Magnesium Carbonate
Harshaw Chemical Co.
Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.
Manganese Dioxide
Foote Mineral Co.
Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Corhart Refractories Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
Masks (Breathing)
The DeVilbiss Co.
Willson Products, Inc.
Metals (Porcelain Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.
Microscopes (Polarizing)
Bausch & Lomb Optical Co.
Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.
Mixers (Batch)
Lancaster Iron Works, Inc.
Mold Sanders
Lancaster Iron Works, Inc.
Muffles (Furnace)
Allied Engineering Co.
Carborundum Co. (*Carbofrax*)
Chicago Vitreous Enamel Product Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Frazier-Simplex, Inc.
Norton Co.
Pittsburgh Plate Glass Co.
Muffles (Laboratory)
Electro Refractories & Alloys Corp.
Mullite (Refractories)
Electro Refractories & Alloys Corp.
Muriatic Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Needle Antimony
Harshaw Chemical Co.
Nickel Salts
Harshaw Chemical Co.
Nitrates (Cobalt, Sodium)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.
Nitre
Harshaw Chemical Co.
Non-Gro Refractories
Electro Refractories & Alloys Corp.
Norbide (Norton Boron Carbide)
Norton Co.
Olivine
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Opacifiers
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I. & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.
Overglaze Colors
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Oxides
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc. R. & H. Chemicals Dept.
Harshaw Chemical Co.
Metal & Thermit Corp.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.
Palladium Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Pins
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.
Potters Supply Co.
Platinum Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Polariscopes
Bausch & Lomb Optical Co.
Frazier-Simplex, Inc.
Porcelain Enameling Service (Practical)
American Rolling Mill Co.
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.
Porcelain Enamels
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.
Potash (Carbonate)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc. R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Solvay Sales Corp.
The Vitro Mfg. Co.
Producer Glass Plants
Frazier-Simplex, Inc.
Pug Mills
Lancaster Iron Works, Inc.
Pyrites (Natural Iron Sulphide)
Foote Mineral Co.
Pyrometer Tubes
Carborundum Co.
Electro Refractories & Alloys Corp.
Montgomery Porcelain Products Co.
Pyrometer Tubes (Refractory and Hard Porcelain)
Denver Fire Clay Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.
Pyrometers (Optical, Radiation, Surface, Immersion, Needle)
Pyrometer Instrument Co.
Pyrometric Cones
The Edward Orton, Jr., Ceramic Foundation
Raw Material Handling Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
Refractometers
Bausch & Lomb Optical Co.
Refractories
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Kentucky-Tennessee Clay Co.
Norton Co.
Pittsburgh Plate Glass Co.
Refractory Materials
Carborundum Co.
Chicago Vitreous Enamel Product Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Kentucky-Tennessee Clay Co.
Norton Co.
Pittsburgh Plate Glass Co.
Sant, Richard C.
Titanium Alloy Mfg. Co.
Represses (Automatic)
Lancaster Iron Works, Inc.

Respirators
Chicago Vitreous Enamel Product Co.
Cover, H. S.
The DeVilbiss Co.
The Hommel Co., O., Inc.
Willson Products, Inc.

Rutile
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Saggers
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.
Potters Supply Co.

Salt Cake
American Potash & Chemical Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Sandblast Helmets
Willson Products, Inc.

Sand Grinder and Sifters
Lancaster Iron Works, Inc.

Saponin
The Hommel Co., O., Inc.

Selenite of Sodium
Drakenfeld & Co., B. F.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Selenium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Sheets (Enameling Iron)
American Rolling Mill Co.
Bethlehem Steel Co.

Silica (Fused)
Electro Refractories & Alloys Corp.
The Hommel Co., O., Inc.

Silicate of Soda
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
The Hommel Co., O., Inc.
Harshaw Chemical Co.

Silicon Carbide
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.

Silicon Carbide Firesand
Carborundum Co.

Sillimanite Refractories
Electro Refractories & Alloys Corp.

Sillimanite (Synthetic)
Pittsburgh Plate Glass Co.

Slabs (Furnace)
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.
Pittsburgh Plate Glass Co.

Soda Ash
American Potash and Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pittsburgh Plate Glass Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Sodium Antimonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Sodium Fluoride
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Sodium Metasilicate
Harshaw Chemical Co.

Sodium Nitrite
Harshaw Chemical Co.

Sodium Silica Fluoride
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Sodium Uranate
Harshaw Chemical Co.

Soot Blowers
Frazier-Simplex, Inc.

Special Machines
Frazier-Simplex, Inc.

Spar
Ceramic Color & Chemical Mfg. Co.
Consolidated Feldspar Corp.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Spray Booths
The DeVilbiss Co.

Spraying Equipment
The DeVilbiss Co.

Spurs
Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Steel Plate Construction
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Stilts
Potters Supply Co.

Sulfuric Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Talc
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.

Tanks
Frazier-Simplex, Inc.

Tank Blocks
Corhart Refractories Co.
Pittsburgh Plate Glass Co.

Tanks (Pickle)
Chicago Vitreous Enamel Product Co.
The Hommel Co., O., Inc.

Tanks for Raw Material Steel or Concrete
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Tile (Floor)
Norton Co.

Tile (Muffle)
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
Chicago Vitreous Enamel Product Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.
Pittsburgh Plate Glass Co.

Tile (Wall)
Denver Fire Clay Co.

Tin Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Titanium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
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FUEL CONSUMPTION DATA

For a large continuous tank on two consecutive runs

	TOTAL DAYS LIFE	TOTAL PRODUCING DAYS	TOTAL GLASS DELIVERED (TONS)	TOTAL GAS (M) CONSUMED	USEFUL GAS (M) 3000 x GLASS PRODUCED	TOTAL WASTE GAS (M)	WASTE GAS PER DAY (M)	TOTAL WASTE GAS FOR TOTAL IDLE DAYS	TOTAL GAS CONSUMED ON OPERATING DAYS	CU. FT. GAS PER TON OF GLASS
FIRST RUN	577	447	46,326	417,978	138,978	279,000	484	62,920	355,058	7,664
SECOND RUN	708	637	76,446	562,400	229,338	333,062	470.4	33,398	529,002	6,920

These tabulations are for the same bridgewall tank, on two consecutive runs, manufacturing soda lime glass. It has a melting area of 1,000 square feet.

DOES THIS SEEM REASONABLE TO YOU?

THE data chart above is for two consecutive runs of a large continuous tank designed and built in early 1934 by a competent engineering firm.

As originally built, this tank contained 57.25 tons of Corhart Electrocast.* *In its first campaign (577 days) it produced the results tabulated in the first line of the chart.*

In June, 1935, this furnace was repaired in identical design, but the use of Cohart was extended to 87 tons—an increase of 29.75 tons or 52% . . . *The second line of the table above shows the results obtained on this second campaign, a run of 708 days.*

May we emphasize the following points:

The total fuel consumed per ton of glass produced has been reduced 9.7%.

The glass tonnage of this furnace has been increased by 30,120 tons, an increase of 65.0%.

The lower fuel cost per ton of glass produced has been realized simultaneously with a 52% increase in the amount of Corhart used. Cohart takes no credit for this improved fuel performance, except that the presence of our material makes possible the conditions necessary for highest efficiency.

From all these facts we deduce two conclusions which seem eminently true and reasonable to us. Do they to *you*?

(1) THE FUEL EFFICIENCY OF A GLASS FURNACE IS A MATTER OF ENGINEERING, DESIGN, AND OPERATION. IT IS NOT A FUNCTION OF THE MATERIALS OF WHICH THE SIDEWALLS ARE CONSTRUCTED.

(2) The use of better refractory material permits longer furnace campaigns, higher temperatures and greater tonnages per day. These factors combine to spell maximum efficiency.

If you are looking for *maximum efficiency*, we sincerely believe you are looking for Corhart Electrocast.* We would appreciate your comments.

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VOLUME 17 FEBRUARY, 1938 NUMBER 2

PAPERS

TEMPERATURE CONDITIONS IN BOILER FURNACES*

By Ralph A. Sherman

Abstract

This paper discusses the factors that determine the temperatures that will be attained by the gases of combustion and by the refractories in furnaces burning various types of fuels and presents experimental data on temperatures in boiler furnaces. The conclusion is reached that, because of the many variables involved, the temperatures are not subject to accurate calculation or prediction. In boiler furnaces in which refractories are used at the present time, the temperatures attained by the brick are below those at which the refractories will fail from fusion, but they are generally well above the temperatures at which the slags from coal ash will attack the refractories.

I. Introduction

The word "refractory" always brings to one's mind the thought of high temperatures; it is important, therefore, to consider the temperature conditions in boiler furnaces as they determine the temperatures reached by the refractories. Although, as is well known, the pyrometric cone equivalent of first-grade refractories lies above the maximum temperatures attained in boiler furnaces, refractories fail from other causes at temperatures below their P.C.E. They will deform under load and the temperature at which they flow decreases as the load increases. The length of time that the temperature is maintained is also important in deformation. Permanent volume changes occur at temperatures below the fusion temperature, and refractories also show a reversible thermal expansion which may cause cracking or spalling under certain rates and intervals of temperature change. Most important of all, the ash of the fuel may attack the refractory at temperatures well below its fusion temperature. This attack is the most frequent cause of failure of refractories in coal-fired furnaces.

During the period from 1924 to 1928, the Bureau of Mines, in coöperation with the Special Research Committee on Boiler Furnace Refractories of the A.S.M.E., conducted an exhaustive experimental investigation of the conditions of temperature, gas composition, gas velocity, and ash and slag composition in nine combinations of various types of boiler furnaces and of various fuels.

Note: The results of these investigations were reported in a series of eleven progress reports in the technical journals and the most important data were summarized in "A Study of Refractories Service Conditions in Boiler Furnaces," *U.S. Bur. Mines Bull.*, No. 334 (1931); *Ceram. Abs.*, **10** [6] 438 (1931).

Although many advances have been made in the design of boiler furnaces since that time, in the larger furnaces the most important changes have been toward the elimination of difficulties with refractories by the elimination of refractories, *i.e.*, by the use of water-cooled walls of various types. Those furnaces in which refractories are used today, and they are many, are much of the

* Presented at a meeting of the Refractories Division, American Ceramic Society, Bedford Springs, Pa., September 3, 1937. Received September 13, 1937.

same type as those included in the experimental investigations. The published data from these investigations have long been available and may be familiar to most who are interested in boiler-furnace refractories. Because, however, they are still applicable to present conditions and because they have not been superseded by other data, they must serve as data for the present discussion.

The purpose of this paper is to discuss the factors that determine the temperatures in boiler furnaces and to show the relation between these temperatures and the temperatures of the refractories. The experimental data from the published reports will be used to illustrate the various points.

II. Factors That Determine Furnace Temperatures

When any fuel is burned, the temperature attained depends upon three principal factors as follows: (1) the rate of heat liberation, which is determined by the rate of firing of the fuel, F, and its calorific value, V; this may be expressed as $Q = FV$; (2) the heat capacity of the products formed in the combustion, which is determined by the specific heat, C, and the weight of the products per unit weight of fuel, W; and (3) the rate of heat loss to the surroundings, R.

III. Theoretical Temperature of Combustion

If we can imagine a closed box in which the combustion takes place in such a manner that no heat is lost from the flame, all of the heat in the fuel would be in the products of combustion, and the so-called theoretical temperature of combustion would be realized. This may be expressed as

$$FV = TCWF,$$

or

$$T = \frac{V}{CW} \qquad (1)$$

The interesting part of this equation is that it shows, under these conditions of no heat loss, that the temperature would be independent of the rate of heat liberation as the quantity, F, cancels out.

The theoretical temperature of combustion is not of particular interest in a practical way as it is never realized. Not only is heat always lost from the flame to surroundings, but dissociation of carbon dioxide and water-vapor into their elements absorbs heat and prevents the attainment of the theoretical temperature.

One more factor that is most readily discussed in relation to equation (1) is worthy of mention. As the temperature is inversely proportional to the weight of the products of combustion, it would appear that the theoretical temperature of combustion might vary over wide limits, inasmuch as the weight of oxygen or air required for the combustion of a unit weight of different fuels varies widely. Over a wide range, however, for either liquid, gaseous, and solid fuels, the weight of air required is approximately proportional to the calorific value. Roughly, about 0.75 lb. or 10 cu. ft. of air are required for each 1000 B.t.u. of the calorific value. A coal having 12,000 B.t.u. per lb. requires theoretically about 9 lb. of air per pound of coal, and a natural gas of 1000 B.t.u. per cu. ft. requires about 0.75 lb. or 10 cu. ft. per cubic foot of gas.

Except for gases that are largely diluted with inert gases, such as producer gas or blast-furnace gas, the weight or volume of the products of combustion will not vary greatly per 1000 B.t.u. liberated and, because of this, the theoretical temperatures of combustion will not vary over extremely wide limits. The other factor that determines the flame temperature is the specific heat; this will vary with different fuels, depending upon the relative proportions of carbon and hydrogen in the fuels.

IV. Actual Temperatures of Combustion

The temperatures actually attained in the combustion of fuels in boiler furnaces depend on the factors in equation (1) and upon the amount of excess air supplied and the rate of heat loss to the surroundings. This may be expressed as follows:

$$FV = TCWF + R,$$

or

$$T = \frac{FV - R}{CWF} \qquad (2)$$

The rate of fuel supply, F, can not now be canceled from the equation, and the temperature is dependent on the rate of heat liberation. Because, to avoid loss due to incomplete combustion, it is always necessary to supply an excess of air over the theoretical requirements, the temperature will be decreased as the excess is increased.

If the rate of heat lost from the fuel bed or flame to the walls and the boiler tubes can be evaluated, and it is possible to do this approxi-

mately although difficult to obtain accurately, the temperature that would obtain at the exit of a boiler furnace may be calculated. This has been the purpose of many of the mathematical and some of the experimental investigations of recent years. This temperature is of value in relation to the design of boilers but is of little value in relation to the temperature of the refractories. This method assumes that the heat of the fuel is liberated instantaneously at a point, but that the fuel does not burn instantaneously. Because a certain time is required for combustion and because heat is lost from the flame or fuel bed as the fuel burns, the temperature never attains the maximum that it would if instantaneous combustion did occur.

Figure 1 shows an example of the difference in the maximum temperature of a flame and the position of the maximum temperature in the furnace when the same rates of gas and air supply were used in the same furnace. These data were obtained in an investigation of the radiation from luminous and nonluminous natural gas flames.[1] The differences were caused by the degree of mixing of the gas and air at the burner nozzle. The nonluminous flame was obtained by complete premixing of the gas and air; combustion was extremely rapid as the maximum temperature had been reached between the nozzle and the first point of measurement, one foot away. The semi-luminous flame was the result of partial mixing, and the luminous flame was the result of allowing the gas and air to mix as they flowed through the furnace.

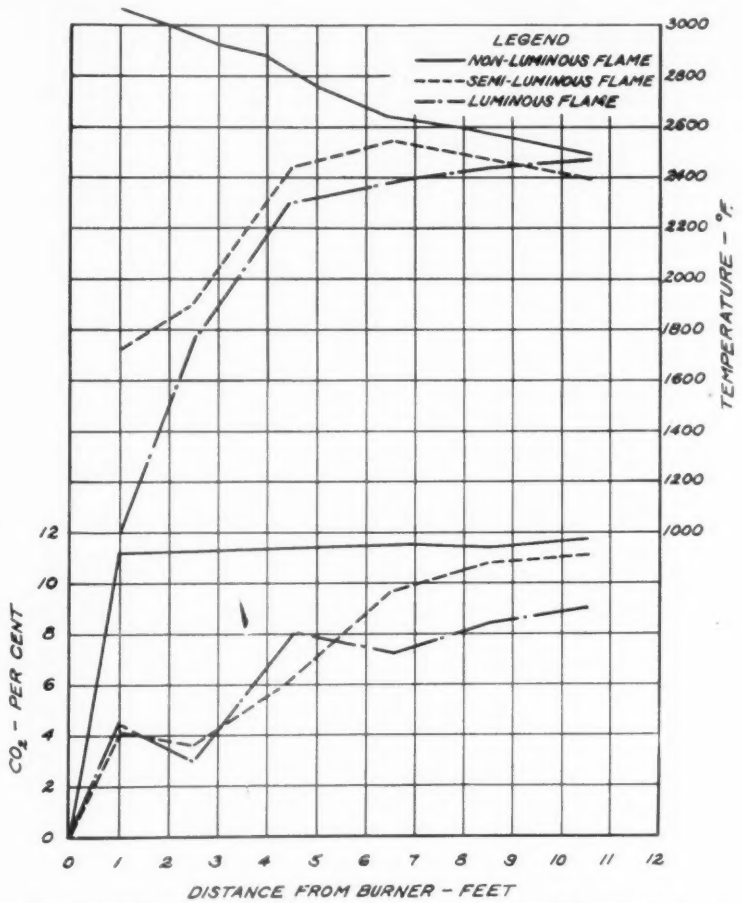

FIG. 1.—Effect of rate of combustion on temperature of flame of natural gas. (Rate of heat liberation, 2,800,000 B.t.u. per hr.; theoretical air supply.)

Similar variations in the distribution of the intensity of combustion occur in the fuel bed and combustion space of stoker-fired boiler furnaces.

[1] R. A. Sherman, "Radiation from Luminous and Non-Luminous Natural Gas Flames," *Trans. Amer. Soc. Mech. Engrs.*, **56** 177 (1934); *Ceram. Abs.*, **14** [11] 288 (1935).

In traveling-grate stokers, the windbox is generally divided into a number of compartments in which the pressure, and thus the amount of air delivered to a given area of the fuel bed, can be varied. Even without the possibility of control of the air supply, variations because of clinkering or coking of the fuel will cause local variations in the rate of burning.

In underfeed-stoker fuel beds, variations in the intensity of combustion in different parts of the fuel bed are common. Because more strongly coking coals are used on these stokers, the coal cokes into large masses which are broken up by the agitation provided by the pressure of rams and pusher blocks. The resultant fuel to be burned is of larger size than that fired and thick fuel beds result. Because of the chance breaking up of the coke, because of clinker masses covering the tuyères, or because of blowholes formed in the fuel bed, great variations in the rate of burning can occur in local spots and very high or very low temperatures may occur.

In the combustion space above the fuel bed of the stoker, similar variations in combustion rate occur. There may arise from one part of the fuel bed gases high in CO which is burned when this stream meets a stream of gas containing free oxygen.

In pulverized-coal-fired furnaces, differences in the rates of combustion are found even in furnaces which are of quite similar design. Figure 2 shows an excellent example of this taken from the data obtained in pulverized-coal furnaces at the Cahokia and East Peoria generating stations. The burners in the two boilers were similar in that they fired downward through the arch; the flame was directed downward toward a water-tube slag screen at the bottom of the furnace and turned upward to the boiler tubes in a U path. Although the temperatures are not directly comparable in

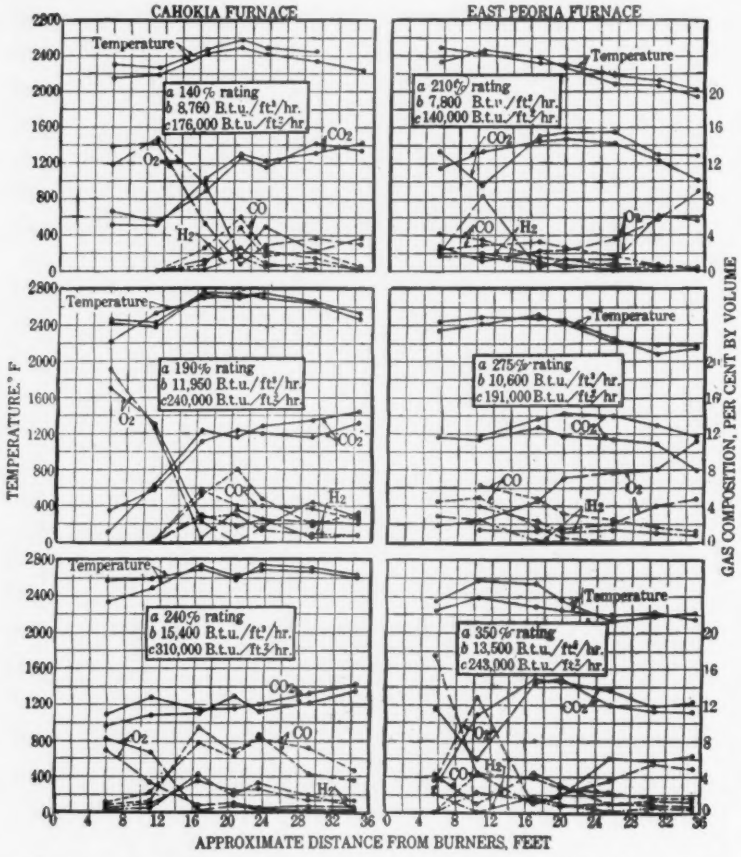

FIG. 2.—Temperature and composition of gases at points 4 feet from the side wall in furnaces burning pulverized Illinois coal. (*a*) Boiler load in per cent of nominal rating; (*b*) heat liberation in B.t.u. per hour per cubic foot of combustion space; (*c*) heat liberation in B.t.u. per hour per square foot of projected area of radiant heating surface.

that the rates of heat liberation are not exactly the same, the difference in the shape of the temperature and gas-composition curves in the two furnaces is clearly seen. The mixing of the coal with the air was accomplished earlier in the East Peoria furnace, and the maximum temperature occurred earlier in the path of the flame. The most intense mixing and combustion occurred at the turn in the U in the Cahokia furnace and the maximum temperatures were found there.

This discussion of the variations in the intensity of combustion in different types of furnaces has been presented as a basis for the conclusion that, because of these differences, it is impossible to make any calculations of the temperatures that will be found in various parts of various types of boiler furnaces.

The belief is sometimes held that the combustion of pulverized coal will result in higher temperatures than can be obtained in stoker-fired furnaces. Oil-fired furnaces are also reputed to have higher temperatures than those fired with coal. Sound reasons for this possibility exist because (1) of the better chances for mixing the air with the pulverized or atomized fuel, combustion may be completed with a lower excess of air than when burning solid fuel, and (2) the better mixing promotes more rapid combustion in the early part of the flame and, therefore, higher temperatures. As a matter of fact, however, higher temperatures were not found in the course of the experimental investigations either in the pulverized-coal-fired or oil-fired furnaces than were found in stoker-fired furnaces.

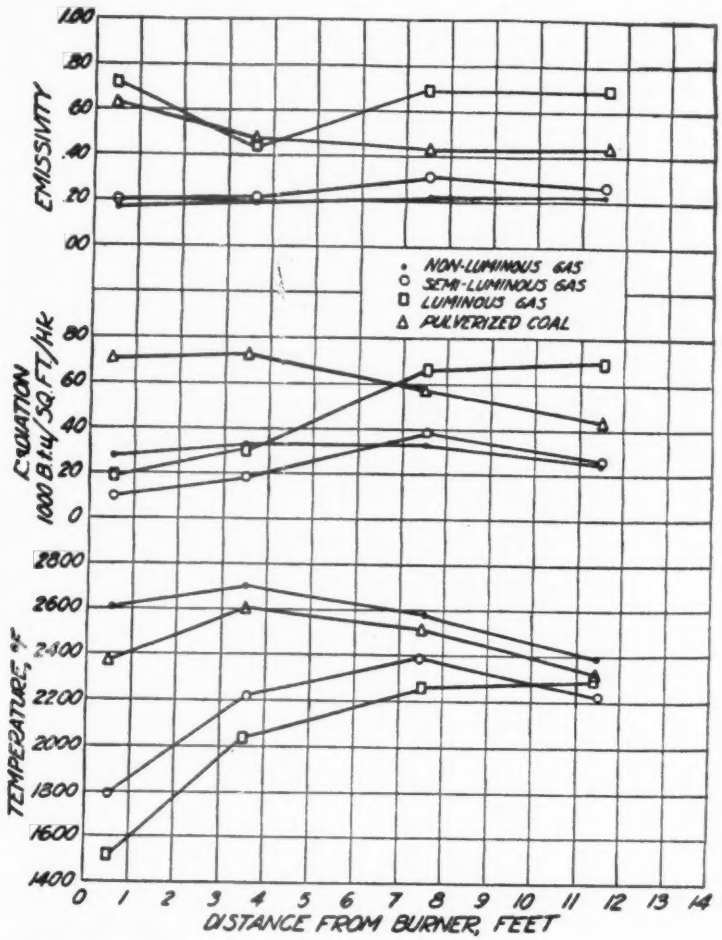

FIG. 3.—Temperature, radiation, and emissivity of natural-gas and pulverized-coal flames.

The maximum temperature of the gases that was measured in any furnace did not exceed 2900°F. The statement was made in the *Bulletin*, ". . . . .but the possibility can not be ignored

that higher temperatures may occur under unusual conditions." In some later investigations in a pulverized-coal-fired boiler furnace, a single instance of a temperature of 3000°F immediately in front of the burner was found.

V. Relation of the Temperature of the Furnace to the Temperature of the Refractories

Heat is transferred from the fuel bed and the flame to the refractories by the three familiar methods of conduction, radiation, and convection. It had long been suspected that radiation played the most important part in the transfer of heat under conditions of boiler furnaces, and some experimental data were available at the time that the investigations of refractories service conditions were made. Since that time, many more experimental and mathematical data have accumulated that confirm the importance of radiation and show the part that radiation from flames, including nonluminous flames, plays in heat transfer in furnaces.

Figure 3, taken from data obtained in the investigation of radiation from flames,[2] shows the temperatures, radiation, and emissivity of three types of natural-gas flames and pulverized-coal flame in an experimental furnace. The emissivity, that is, the ratio of the radiation from the flame to that of a perfectly black body at the same temperature, of the entirely nonluminous flame was 0.2 throughout the length of the furnace. This is the maximum that nonluminous flames can have as they radiate only in narrow bands of the spectrum. Although the furnace was only $3^1/_2$ feet in diameter, the emissivity of the pulverized-coal flame varied from 0.6 to 0.4 and that of the luminous gas flame was as high as 0.7.

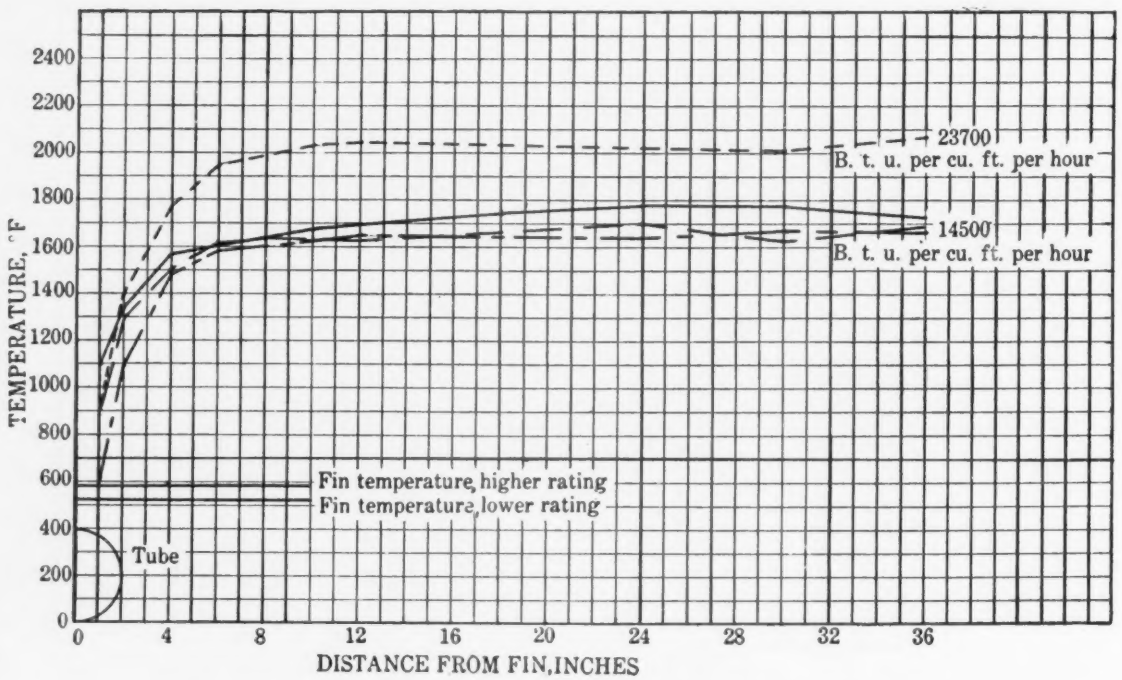

FIG. 4.—Effect of fin-tube water walls on temperature of the furnace gases.

The emissivity increases with thickness of flame, and calculations show that if the flame had been 15 feet in thickness, as flames are in larger boiler furnaces, the emissivity would have been more than 0.9. If the flame had been 20 feet thick the emissivity would have been greater than 0.97, even at the end of the flame where the carbon was practically entirely burned out of the flame, although the ash was still carried by the gases.

The emissivity and the absorptivity of a flame are equal, *i.e.*, if a flame has a high emissivity for radiation it likewise has a high absorptivity. The practical significance of this is sometimes overlooked. It means that if a flame of high emis-

[2] R. A. Sherman, "Burning Characteristics of Pulverized Coals and Radiation from Their Flames," *Trans. Amer. Soc. Mech. Engrs.*, **56**, 401 (1934); *Ceram. Abs.*, **14** [11] 287 (1935).

sivity is between two surfaces it will shield the radiation from one surface to the other. For example, a flame of high emissivity above a fuel bed at high temperature may effectively reduce the radiation from the bed to the refractory walls of the furnace. Such a flame between a water-tube rear wall and a refractory front wall, on the other hand, reduces the effectiveness of the water-tube wall in cooling the refractory wall, although indirectly it will be effective as it will reduce the temperature of the flame.

Figure 4 presents data of some value in connection with the effect of the water-tube wall on the flame temperature although it is admitted that, because the temperatures were not taken with a shielded thermocouple, the temperatures near the tubes were undoubtedly affected by radiation to the tubes. It would appear from these data that the temperature of the flame was affected by the cool surface only to a distance of about eight inches from the wall. The temperature of the entire mass of gas was, however, probably lower than it would have been if the wall had not been cooled.

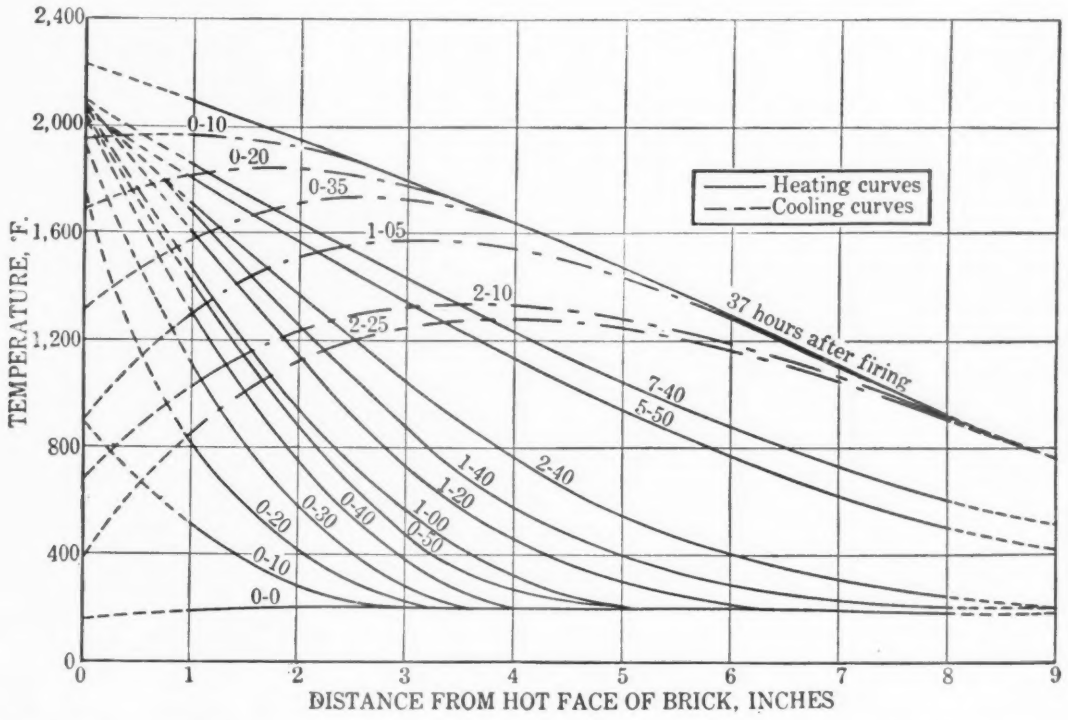

FIG. 5.—Temperature gradients through a brick in a 13½-inch wall of a pulverized-coal-fired boiler furnace. Figures on curves show time in hours and minutes from lighting or shutting off burners.

VI. Calculation of Refractories Temperatures

Lacking definite information at the time that the *Bulletin* was written, a simplified method for the calculation of the relation of the temperature of the refractories to that of the flame was adopted. It assumed an effective temperature of the flame or fuel bed and also that the heat was transferred by radiation with an emissivity for the flame of 0.9. In view of the information obtained since that time, this is probably not so incorrect. The rate of heat transfer to the wall is calculated as follows:

$$Q = 1723 \times p \left[\left(\frac{T_f}{1000} \right)^4 - \left(\frac{T_{hs}}{1000} \right)^4 \right] \quad (3)$$

Where Q = rate of heat transfer (B.t.u./sq. ft./hr.).
p = emissivity.
T_f = effective absolute temperature of flame or fuel bed (°F).
T_{hs} = absolute temperature of hot surface (°F).

By the use of this equation, the rate of heat transfer to walls with various assumed temperatures may be calculated as well as a coefficient of transfer, h_f, in B.t.u. per sq. ft. per hr. per °F, similar to the familiar coefficient of thermal conductivity, k.

The temperature of the hot surface of a wall depends upon the rate of heat transfer (1) to the wall, (2) through the wall, and (3) from the cool surface of the wall. Under conditions of thermal equilibrium, these three must be equal, and, having familiar formulas for the latter two and using the equation given for the transfer to the hot surface, the three may be set up as equalities and the temperatures at the various points in the system may be calculated. It is unnecessary to go through the entire calculations, but the equation for the overall coefficient, U, of transfer from the furnace to the air outside is worthy of notice.

$$U = \frac{1}{\frac{1}{h_f} + \frac{L}{k} + \frac{1}{h_a}} \qquad (4)$$

Where h_f = coefficient of transfer to the hot surface (B.t.u. per sq. ft. per hr. per °F).
L = thickness of the wall (inches).
k = thermal conductivity of refractory (B.t.u. per sq. ft. per hr. per in. thickness per °F).
h_a = coefficient of transfer from cool surface of wall (B.t.u. per sq. ft. per hr. per °F).

If the value of one of the resistances, the reciprocals in the denominator of the equation, is much greater than the others, it becomes the factor that largely determines the overall coefficient of transfer. An example of this is given in the *Bulletin* as follows: Assume two 18-inch walls with still air on the cool surface, one made up of fire brick, the other of silicon carbide, with an effective flame temperature of 2800°F. The overall coefficients of transfer will be as follows:

For firebrick wall

$$U = \frac{1}{\frac{1}{217} + \frac{18}{10} + \frac{1}{3.6}}$$

$$= \frac{1}{0.0047 + 1.8 + 0.28} = 0.546$$

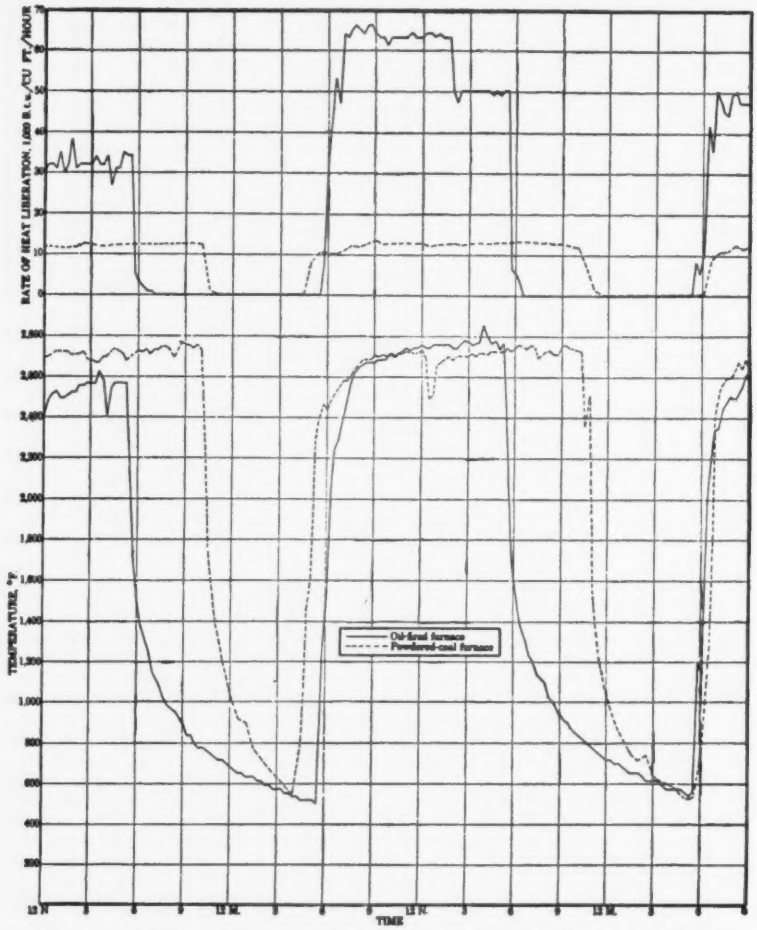

FIG. 6.—Relation of temperature to rate of heat liberation. Curves show temperature at $^1/_2$ inch from face of brick in hottest zone of side walls of pulverized-coal-fired and oil-fired furnaces.

For silicon-carbide wall

$$U = \frac{1}{\frac{1}{211} + \frac{18}{100} + \frac{1}{8.9}}$$

$$= \frac{1}{0.0046 + 0.18 + 0.11} = 3.39$$

The resistance of transfer from the flame to the wall in both examples is so much the smallest of the three resistances that relatively large changes in this value would not materially affect the overall value. In the calculation of the heat transfer coefficient through the firebrick wall, the resistance of the wall is so much larger than that of the transfer from the wall to the air that large changes in the latter would not materially affect the overall transfer. In the silicon-carbide wall, the resistance of the brick is of similar order to that of the wall to the air; similar changes in either would have similar effects on the overall coefficient.

TABLE I

TEMPERATURE OF SURFACE OF WALLS UNDER VARIOUS CONDITIONS

	t_f = 2800°F t_a = 90°F							
	Fire brick				Silicon carbide			
	V = 0		V = 1200		V = 0		V = 1200	
L	t_{hs}	t_{cs}	t_{hs}	t_{cs}	t_{hs}	t_{cs}	t_{hs}	t_{cs}
27	2796	380	2796	255	2768	940	2765	780
18	2794	450	2794	310	2755	1070	2752	920
9	2789	610	2788	460	2723	1290	2717	1180
4.5	2779	800	2777	635	2675	1520	2666	1430
	t_f = 2400°F t_a = 90°F							
27	2395	340	2395	230	2361	870	2358	700
18	2393	420	2392	300	2346	980	2341	830
9	2386	560	2385	410	2310	1180	2300	1070
4.5	2374	740	2371	580	2256	1380	2242	1290

t_f = furnace temperature. t_a = air temperature.
L = thickness of wall (inches). V = air velocity (ft./-min.).
t_{hs} = temperature of hot face of wall. t_{cs} = temperature of cold face of wall.

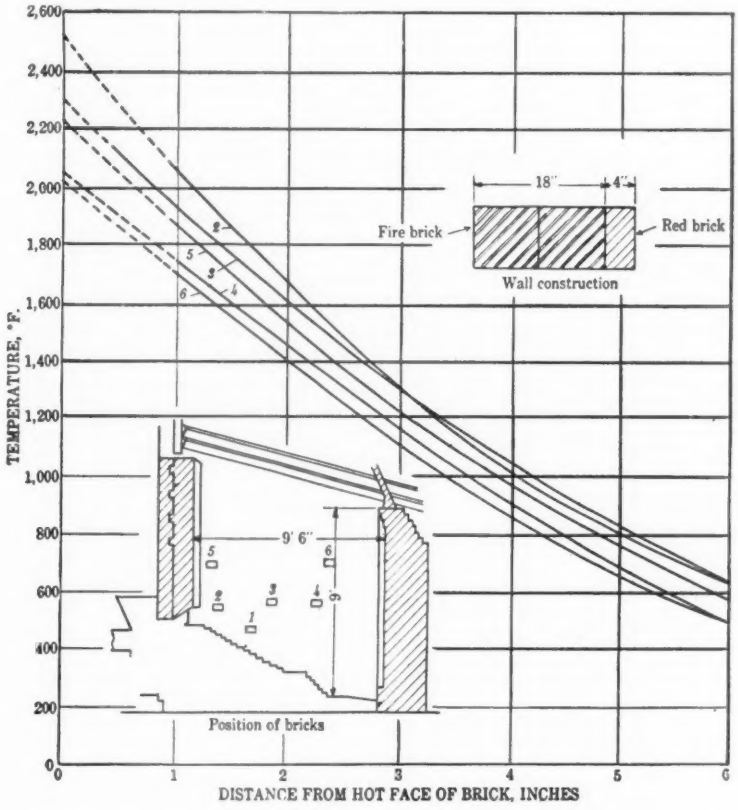

FIG. 7.—Temperatures in brick in walls of furnace burning Pittsburgh coal on an underfeed stoker, 14½ hours after lighting fire. Rate of heat liberation, 40,000 B.t.u. per cubic foot per hour.

VII. Cooling of Refractories

These calculations are of particular value in a consideration of the extent to which the temperature of the hot surface of a wall may be reduced by air or water cooling. Table I shows the results of calculations of the hot and cold surface of firebrick and silicon-carbide walls of various thicknesses with furnace temperatures of 2800° and 2400°F and with still air and air moving at a velocity of 1200 feet per minute on the cool side.

Briefly, these calculations show that the surface temperature of thick firebrick or silicon-carbide walls will closely approach the furnace temperature. In walls as thin as 4.5 inches, the hot surface temperature of a silicon-carbide wall will be materially reduced but that of a firebrick wall will be reduced very little. Movement of air on the cool side will reduce the temperature of the cool side of the wall but has little effect on the temperature of the hot surface.

ture on the hot surface of a wall will be rapid but that the rise of temperature in the interior of the wall will be slow. Figure 5 shows the temperature gradients through a brick in a $13^1/_2$-inch firebrick wall in a pulverized coal-fired boiler furnace. In one hour after lighting this furnace, the hot surface of the wall was at a temperature of 2100°F, but the temperature at 8 inches from the face had scarcely risen. At over 7 hours after lighting the furnace, more heat was still entering

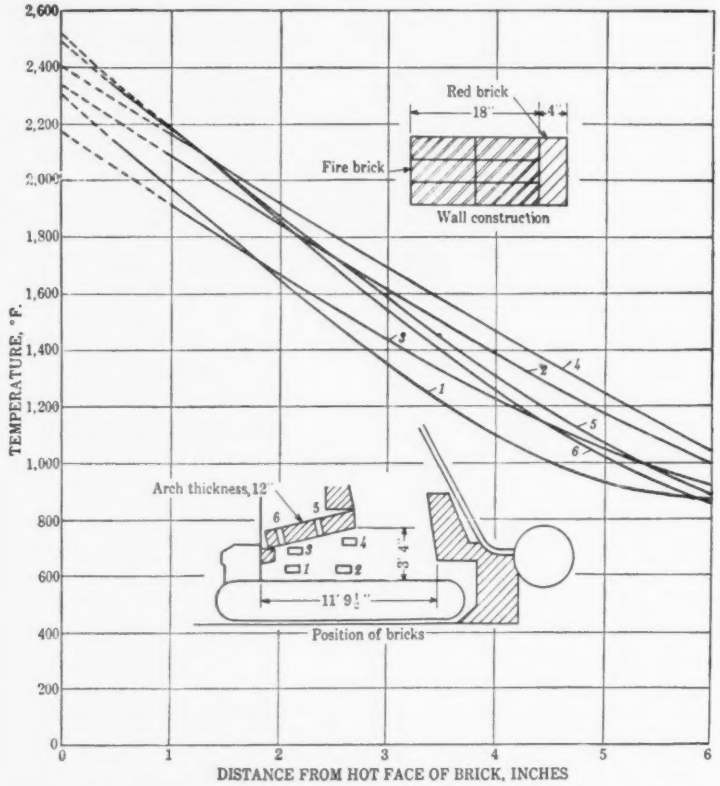

FIG. 8.—Temperatures in brick in walls and arch of a furnace burning Pittsburgh coal on a traveling-grate stoker, $25^1/_2$ hours after lighting. Rate of heat liberation, 30,000 B.t.u. per cubic foot per hour.

For effective cooling of a wall, therefore, it is essential that the section be thin and that it be material of high thermal conductivity. These principles are used in the Bailey-block walls where an iron block is cast onto a thin section of alumina or silicon carbide and machined to fit the water tubes of the wall. The block is clamped tightly to the tubes by means of bolts, and cement is used between the cast-iron block and the tube to obtain a good thermal joint.

VIII. Rates of Heating of Walls

The principles of heat transfer that have been discussed also indicate that the rise of temperature on the hot surface of a wall will be rapid but that the rise of temperature in the interior of the wall will be slow. Figure 5 shows the temperature gradients through a brick in a $13^1/_2$-inch firebrick wall in a pulverized coal-fired boiler furnace. In one hour after lighting this furnace, the hot surface of the wall was at a temperature of 2100°F, but the temperature at 8 inches from the face had scarcely risen. At over 7 hours after lighting the furnace, more heat was still entering the wall than was leaving it. The boiler was fired at practically constant rating for 37 hours when equilibrium was established. The cooling curves, which are indicated by dashed lines, show likewise that the temperature of the hot surface falls rapidly.

Boilers are seldom steamed at constant rating for as long as 37 hours. The rate of firing will change frequently, and the boilers will often be banked for some hours. Thermal equilibrium is, therefore, seldom established in a furnace wall. This means that the temperature of the hot surface will not rise to as nearly equal the temperature of the furnace as indicated by the values

shown in Table I, but neither will it be greatly below it.

IX. Relation of Refractories Temperatures to Rate of Heat Liberation

Figure 6 shows a comparison of the temperatures at one-half inch from the hot face in brick in the hottest parts of a pulverized-coal-fired furnace and an oil-fired furnace, together with the rates of heat liberation in the furnace. Although the rate of heat liberation for a period of three hours, 9 A.M. to 12 M., was 63,000 B.t.u. per cubic foot per hour in the oil-fired furnace and 12,000 in the pulverized-coal-fired furnace, the temperatures in the refractories were practically the same.

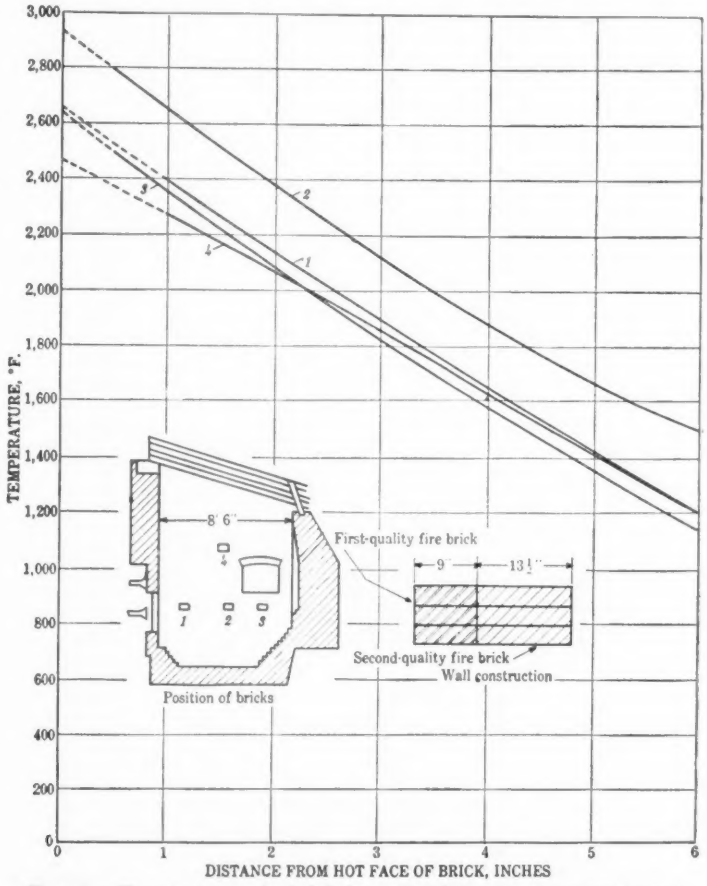

FIG. 9.—Temperatures in brick in walls of furnace burning fuel oil, 11 hours after lighting. Rate of heat liberation, 51,000 B.t.u. per cubic foot per hour.

Several explanations for this may be found. The oil-fired furnace was much smaller than the pulverized-coal-fired furnace; the volumes were 1100 and 11,750 cubic feet, respectively. The boilers were also of much different size; the oil-fired boiler had but 6000 square feet of heating surface, whereas the pulverized-coal-fired boiler had 18,010 square feet. For the same rate of heat liberation the larger the furnace, the higher will be the temperatures in the furnace because the area of the walls and the boiler tubes exposed to the furnace does not increase as rapidly as does the volume. A second explanation, which is probably more largely responsible for the differences in temperature, is that the rates of heat liberation given are based on the entire furnace volume. It has been pointed out that the intensity of combustion in certain zones may be greatly different from the mean rate of combustion. The rates of heat liberation in the two furnaces in the area that determined the temperature of these points in the walls may have been similar although the average rates of heat liberation were so much different.

The temperature curves of Fig. 6 are also of value in indicating that the rate of change of temperature with change in rate of operation of

the boiler was not more rapid in the oil-fired furnace than in the pulverized-coal-fired furnace. Because spalling is often a serious cause of failure of refractories in oil-fired furnaces, it has been sometimes assumed that the rate of temperature change in the walls is extremely rapid.

X. Typical Temperatures of Refractories in Boiler Furnaces

Figures 7, 8, 9, and 10 show, respectively, typical temperature gradients through brick in the walls of furnaces fired with an underfeed stoker, with a traveling-grate stoker, with fuel oil, and with pulverized coal. These curves show that the temperature at the hot face of the brick will vary appreciably in various parts of a furnace. It cannot be stated with assurance that the hottest parts of other similar furnaces will be the same as those given but these are typical.

In the underfeed stoker-fired furnace, the highest temperature shown was just above the fuel bed near the front wall. The lowest temperatures were near the back of the side wall over the extension grates. In the furnace with the traveling-grate stoker, the highest temperatures were at the face of the arch which was but a short distance above the incandescent fuel bed and almost parallel to it.

The extrapolated surface temperature of the brick at position 2 in the oil-fired furnace was higher than any temperature of the gases found in this furnace. This was repeatedly true during the course of the experiments. No valid explanation was found for it, but the explanation proposed was that some type of surface combustion occurred on the wall at this point as this was the point of flame impingement on the wall. The gases at this point contained considerable quantities of combustible gases, CO, H_2, and CH_4, which might have burned within the face of the brick.

The temperatures in the wall of the furnace fired with pulverized coal show the effect of the

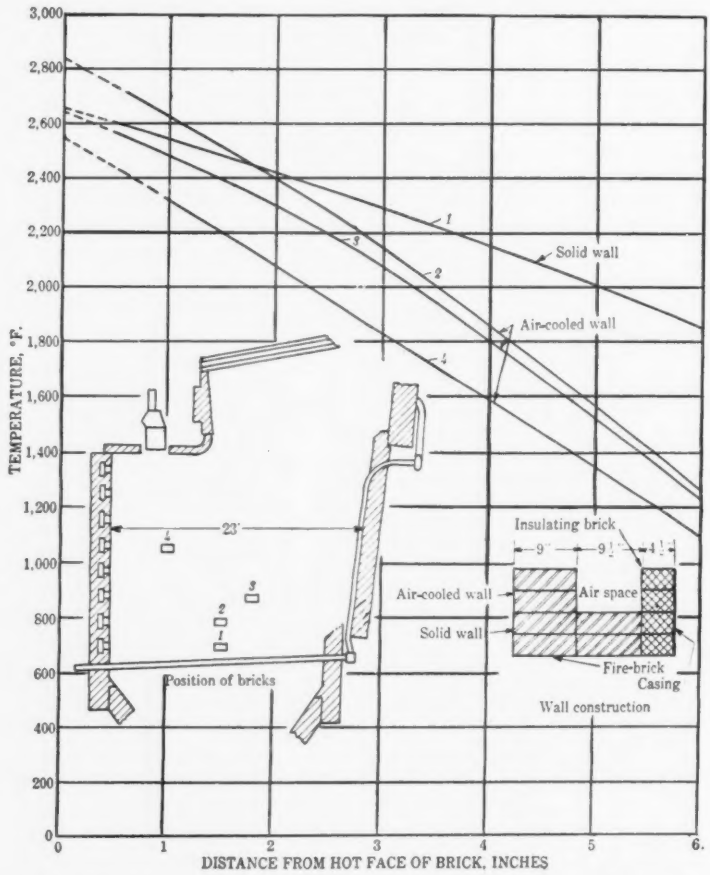

FIG. 10.—Temperatures in brick in walls of furnace burning pulverized Illinois coal, 30 hours after lighting. Rate of heat liberation, 11,600 B.t.u. per cubic foot per hour.

air cooling on the gradient through the wall in the temperatures of brick Nos. 1 and 3. The surface temperatures were practically the same, but the gradient through the air-cooled wall was about twice as great as through the solid wall.

XI. Conclusions

The discussion and data that have been presented on temperature conditions within the combustion space and in the walls of boiler furnaces show that, because of the many variables involved, the temperatures are not subject to accurate calculation or even to prediction by comparison. The temperatures attained in the fuel bed and flame of boiler furnaces are so high and the hot-surface temperatures of refractory walls will normally approach the furnace temperatures so closely that, although the refractories will not fail from fusion and not often from deformation under load, they will be subject to failure from slag attack. Improvement in the resistance of refractories to slag attack or methods for the lowering of refractories temperatures to a safe point are always in order.

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THE ACTION OF SLAG FROM FUEL IN BOILER FURNACES*

By E. G. Bailey

Abstract

The factors which permit a wider latitude in the design of furnaces for steam boilers than for metallurgical or ceramic processes are discussed. The problems in steam boiler furnace design relating to the action of ash and slag are reviewed, and it is shown that they are generally best solved through the use of some form of furnace water cooling. The development of furnaces for steam boilers to meet the progressive requirements of steam generation are shown in historical sequence by a variety of designs, from thirty or more years ago to the most modern present-day practice. The field for water cooling in furnaces for steam boilers is summarized, and it is pointed out that many small boilers burning fuel with stokers as well as oil or gas continue to use reasonably sized refractory furnaces to a large extent.

I. Introduction

Much greater latitude can be taken in the design and operation of steam boiler furnaces than with furnaces used in metallurgical or ceramic processes. Some of the reasons for these differences are (1) exact temperatures are not required in steam boiler furnaces, (2) wide variations in rates of combustion are needed to meet steam output demands, and (3) water cooling of steam boiler furnaces may be used without increasing the total fuel consu- ion or reducing the efficiency.

These factors lead to the possible use of a wide variety of fuels, and often low-grade fuels are the most economical on a cost-performance basis. All kinds of coal and most other raw, by-product, or waste fuels contain ash. Ash resulting from burning fuel usually forms slag, and it is one of the most important factors controlling the design and operation of furnaces. Slag usually attacks refractory furnace linings; it also tends to foul up the furnace and the boiler heating surfaces and to clog the gas passages.

Many metallurgical and ceramic furnaces requiring high temperatures are fired by ash-free or low-ash fuels, such as natural gas, producer gas, oil, etc. Many furnaces of this class, such as glass furnaces, cement kilns, open-hearth furnaces, etc., must withstand a slag or fluxing agent from the charge, but they have a much more uniform condition to meet, both chemically and thermally, than if they were contending with the variable ash of coal or other ash-carrying fuels.

Although nearly everyone interested in this subject is familiar with the many problems arising from the use of refractory furnaces where ash and slag are present, it is well to enumerate the principal forms of trouble as follows: (1) waste by actual melting or fluxing; (2) spalling, due to one or more of a number of factors, principally vitrification or slag penetration of refractory surface; and (3) adhesion and building out of slag, usually in fuel bed zones or in the upper or cooler part of

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the furnace. This action may result in many losses, such as (*a*) breakage or spalling of refractory, (*b*) indirect damage due to falling of tons of slag or clinker, and (*c*) eyebrows interfering with fuel or air distribution or preventing normal removal of ash.

The efficient burning of fuel involves high temperatures and turbulence, both of which carried to extremes will reduce the life of almost any refractory near the active combustion zone even though there is no ash or slag in the fuel.

The presence of ash from the burning fuel usually lowers the temperature at which the furnace can be operated without undue deterioration of the refractory. The ash from many coals, even high-grade low ash coal, forms a eutectic with a melting point so low that no satisfactory operation can be obtained with any known refractory unless it is cooled in some manner.

II. Historical Survey of Water Cooling

Early efforts at cooling consisted in circulating the air for combustion on the outside, or by letting it flow into the furnace through perforations in the refractory blocks. In fact, all air-cooled walls leak a considerable quantity of air into the furnace, and it is this leakage which aids more in the maintenance of the refractory than the actual conduction through the refractory itself, except in the case of those having a high thermal conductivity.

Water cooling of the refractory in boiler furnaces about fifteen years ago consisted of tubes spaced on 9- to 18-inch centers arranged in front of the walls. The water tubes formed a part of the boiler system and therefore all heat was utilized. This construction, just as with air cooling, added only a relatively small increment to the rate of combustion, beyond which the refractory wasted away by fluxing or spalling in the hotter parts of the furnace and formed a foothold for the building of slag in the cooler parts of the large furnaces which were the order of the day.

Some designers of water-cooled constructions then went to the extreme of using closely spaced tubes or tubes with metal fins. Others used a refractory tile, cooled directly by tubes, or tile cast into iron blocks tightly clamped to reasonably spaced water-cooling tubes. Later constructions consist of tubes with metal studs to which plastic refractory is applied, thus forming a complete facing of refractory which withstands flame impingement, washing by molten slag of the most vicious constituency. In the zones of the furnace where ash is removed dry or semidry, smooth cast-iron blocks or bare tubes chill the slag and prevent its building out and choking the discharge opening.

The composition and fusing temperature of coal ash varies widely. A few are selected from some surveys[1] made a few years ago.

					Ash from bunker "C" oil*		
Source of coal	Kansas	Ill.	Pa.	W. Va.	*H*	*R*	No. 1
Coal ash or slag	Slag	Slag	Slag	Slag			
Ash (%)					0.104	0.050	0.06
SiO_2	27.2	42.1	50.8	54.3	5.0	2.6	9.5
Al_2O_3	12.0	13.9	29.2	30.5	0.5	0.4	13.9
Fe_2O_3 (equivalent)	47.9	35.4	14.1	9.3	5.8	19.5	
CaO	15.2	9.6	4.5	2.8	0.5	1.8	
MgO	1.4	1.2	0.7	1.2	1.9	2.2	Trace
SO_3	2.4	0.7	0.3	0.1	20.8	24.2	61.8 Na_2SO_4
Na_2O and K_2O by difference		1.2	1.9	2.7	16.1	18.8	
Initial deformation (°F)	1905	1910	2170	2350			
Softening temperature (°F)	1970	1945	2300	2530			
Fluid temperature (°F)	2180	2240	2675	2815			
			Acid H_2S group		4.9	11.4	
			TiO_2				
			PbO		Tr	Tr	
			V_2O_5		35.9	11.0	
			Undetermined				14.8

* From other sources.

Neither the average fusing temperature nor the chemical analysis tells the entire story, because there is a pronounced segregation of the various constituents where pyrites, calcite, and high-grade fire clay may be present as a mechanical mixture. For instance, a small percentage of pyrites causes a great deal of damage even

[1] (*a*) P. Nicholls and W. T. Reid, "Fluxing of Ashes and Slags as Related to the Slagging-Type Furnace," *Trans. A.S.M.E.*, **54**, 167–90 (1932); R. P. 54–9.

(*b*) P. Nicholls and W. T. Reid, "Slags from Slag-Tap Furnaces and Their Properties," *ibid.*, **56**, 447–65 (1934); R. P. 56–3; *Ceram. Abs.*, **14** [10] 263 (1935).

though the average composition may appear to be fairly satisfactory. This is evident from microscopic examination of fly-ash particles which show spheres, varying from jet black, brown, gray, and white to transparent. The cumulative effect of a small portion of the ash where certain ingredients are isolated may be very damaging. Even oil with less than 0.1% ash is found to be more and more damaging to refractory furnaces. Oil ash causes vitrification and spalling more than actual wastage by flow.

Ash and slag cause trouble elsewhere than to brickwork. They foul heating surfaces, choke gas passages, restrict output, and decrease efficiency. This calls for a certain degree of cooling of the gases of combustion before entering the tube bank. Boiler-tube spacing has been increased so that a certain accumulation may take place without materially reducing output and at the same time may cool the gases before entering the closely spaced superheater tubes.

Because combustion efficiency and capacity are best attained in hot furnaces, refractory-coated water cooling is used, resulting in furnace temperatures from 2900° to 3150°F near the burners. Slag-tap furnaces result in high ash recovery as it collects on the walls. High temperatures are conducive to complete combustion in the furnace near the burners; the gases are then cooled by bare water walls before they enter the tube bank where gases and fly ash are below the sticky temperature. Refractory walls and insulating brick surround the boiler tubes and the superheater and economizer beyond.

The earlier steam boiler furnaces were completely water cooled, *i.e.*, Lancashire, Cornish, and Scotch, and in general use to this day is the locomotive-type boiler. Such boilers have never been used extensively in this country for stationary use. Horizontal return tubular boilers (Fig. 1) and water-tube boilers (Fig. 2) set 2 to 3 feet, and not over 4 feet, above the grates were in common use about 1900. Rates of combustion and efficiencies were low, largely owing to incomplete combustion and high excess air, alternately or simultaneously.

In 1906, A. Bement and others recommended higher settings, refractory arches, and other means of increasing furnace efficiency. Figure 3 shows such a boiler having a capacity of about 40,000 pounds of steam per hour.

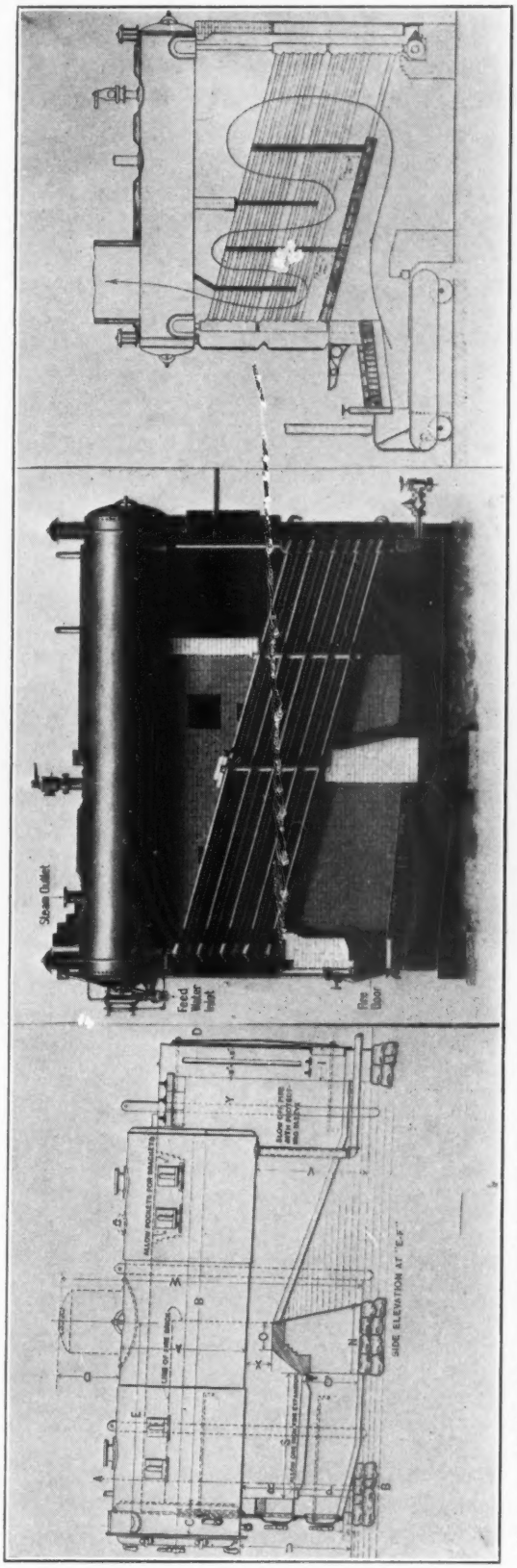

FIG. 1.—Horizontal return tubular boiler of 1900.

FIG. 2.—Water-tube boiler of 1900.

FIG. 3.—Water-tube boiler, proposed improved setting of 1906.

About 1910, the Detroit Edison Company installed boilers (Fig. 4) much larger than anything previously built. These had large high furnaces, more than 26 feet from the fuel bed to the apex of the furnace and 10 feet as the closest heating surface above the fuel bed, and a capacity of 160,000 pounds of steam per hour at 200 pounds pressure and 525°F.

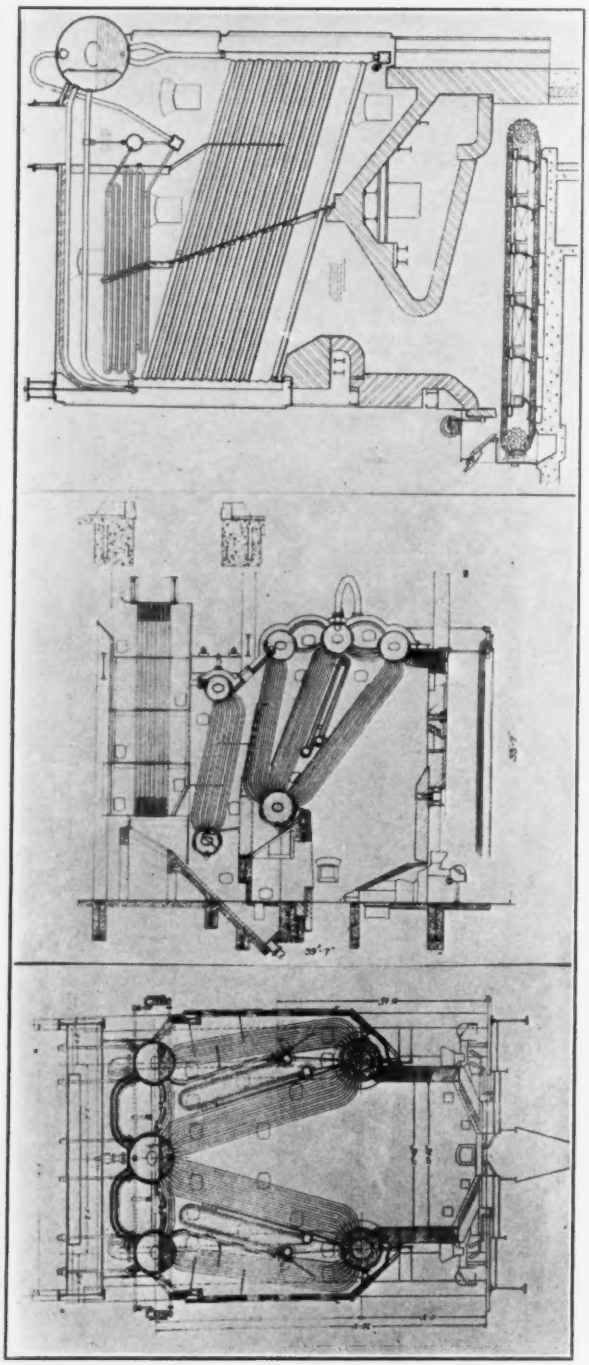

FIG. 4.—The largest boilers of 1910 (Delray Station, Detroit Edison Co.).

FIG. 5.—Higher boiler settings by 1916 (Chester Station, Philadelphia Electric Co.).

FIG. 6.—Chain-grate stokers of 1916.

From about 1916, high boiler settings and underfeed stokers became general in central stations. Figure 5 shows such an installation with about 15 feet from fuel bed to tube bank and a capacity of 145,000 pounds of steam per hour.

At about this time chain-grate stoker-fired boilers were being set higher above the grate and a variety of refractory arch constructions similar to Fig. 6 were being installed. Another chain-grate arrangement (Fig. 7) has the boiler 20 feet above the grate with a different arch arrangement and still no water cooling except a water box at the fuel-bed clinker line just above the stoker. The capacity of this boiler is rated at 150,000 pounds of steam per hour at 650 pounds and 725°F. This was installed in 1924.

Figure 8 shows a boiler with a Murray fin wall in the sides of the furnace only. This was an early application of water cooling in the modern sense and was placed in operation in 1924. It is noted that the water cooling does not extend to the corners and a course of brick was built between the water-cooling tubes and the fuel bed.

Figure 9 is a block-covered water wall, installed in 1925 and is among the first where this type of wall is used with stokers. Here the complete back wall is cooled, but only a portion of the side walls and none of the front wall. Smooth cast-iron blocks were used in the fuel bed zone and refractory-faced blocks in the upper areas. These two kinds of blocks are shown in the lower and upper portions, respectively, of Fig. 27.

A modern stoker-fired boiler and furnace are shown in Fig. 10. The capacity is 424,000 pounds of steam per hour at 950 pounds pressure and 910°F. The furnace is about 50 feet high and is completely water cooled. The lower portions of the back wall and the side walls are constructed of smooth cast-iron blocks on water tubes, as shown in Fig. 27. This is the best construction to prevent adherence of slag at the fuel-bed zone. Fully studded tubes (see upper part of Fig. 28) form the protection immediately above the blocks, and the upper por-

tion of all four walls consists of closely spaced tubes. The larger stoker-fired boilers will undoubtedly continue with substantially complete water cooling.

Figure 11 is a more modern chain-grate stoker with water-cooled side walls and arches, except for the small ignition arch which is refractory. The usual brick side walls extend from the top of the water cooling to the top of the boiler setting. The water-cooled blocks are shown in the lower portion of Fig. 27.

Figure 12 is a three-drum water-tube boiler with a chain grate and a completely refractory setting with suspended arches. Such boilers and settings are being sold and installed today for steam outputs up to 50,000 pounds of steam per hour and 300 pounds pressure. There is still a considerable market for smaller boilers fired with various types of stokers which will use little or no water cooling.

III. Pulverized-Coal Firing

Pulverized-coal-fired furnaces are generally recognized as being more difficult to maintain without water cooling than stoker-fired furnaces. This has been true because pulverized-coal furnaces have been larger and a greater percentage of ash has been carried in suspension and brought into intimate contact with the furnace walls.

The early history of pulverized coal with small furnaces was so limited and unsuccessful that it seems best to start with Fig. 13, showing a large furnace of air-cooled refractory with a few water-cooling tubes across the bottom and up the back wall similar to Fig. 26. This boiler, installed in 1923, was rated at only 190,000 pounds of steam per hour and a furnace liberation of about 10,000 to 12,000 B.t.u. per cubic foot.

Figure 14 is a further modification of an air-cooled pulverized-coal-fired furnace installed in 1926. Even though this boiler is operated with a coal having a very high fusing temperature ash, it subsequently had some water cooling added to the front wall near the down-shot vertical burners.

Figure 15 shows one of the earlier water-cooled pulverized-coal furnaces, which was installed in Chicago in 1926 to burn a low-grade Illinois coal having an ash-fusing temperature of about 1900° to 2000°F at 30,000 B.t.u. per cubic foot per hour.

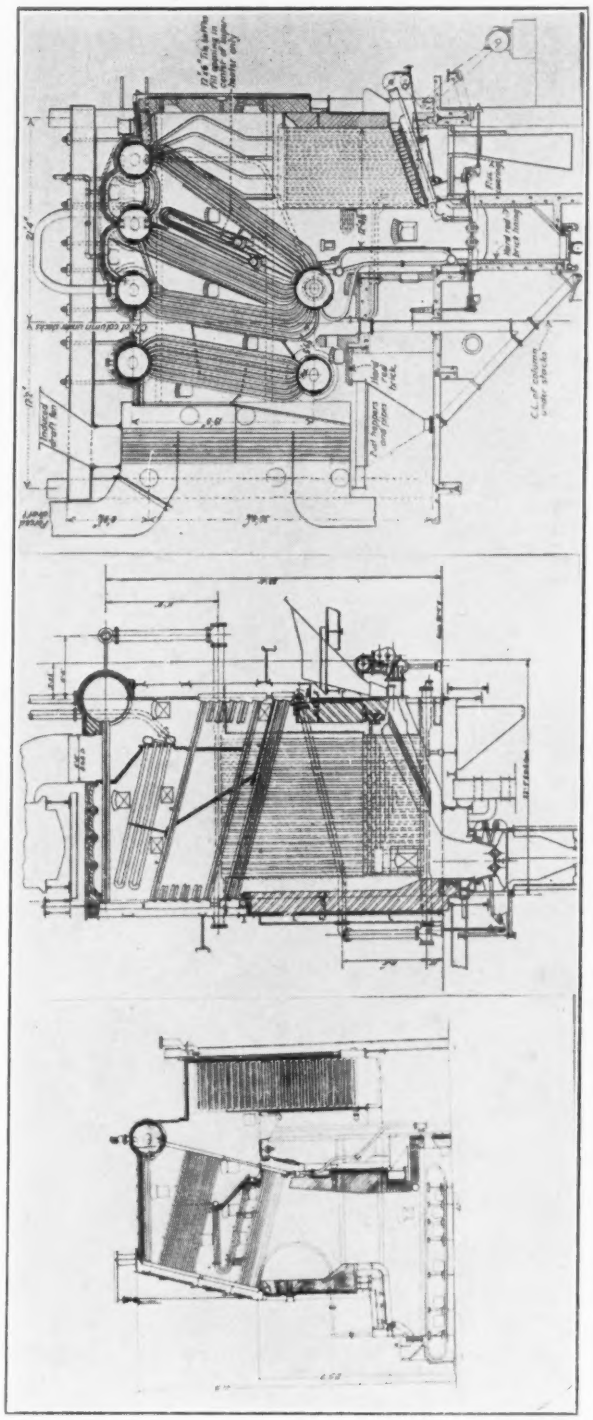

FIG. 9.—Underfeed stoker with Bailey block-covered water-cooled furnace, 1925 (Richmond Station, Philadelphia Electric Co.).

FIG. 8.—Underfeed stoker with Murray fin-tube water-cooled furnace, 1924 (Hell Gate Station, New York Edison Co.).

FIG. 7.—Chain-grate stokers of 1924 with higher settings (Crawford Ave., Commonwealth Edison Co.).

It is noted that the water cooling did not extend entirely up to the boiler tubes and refractory was used for the end of the hopper bottom. Refrac-

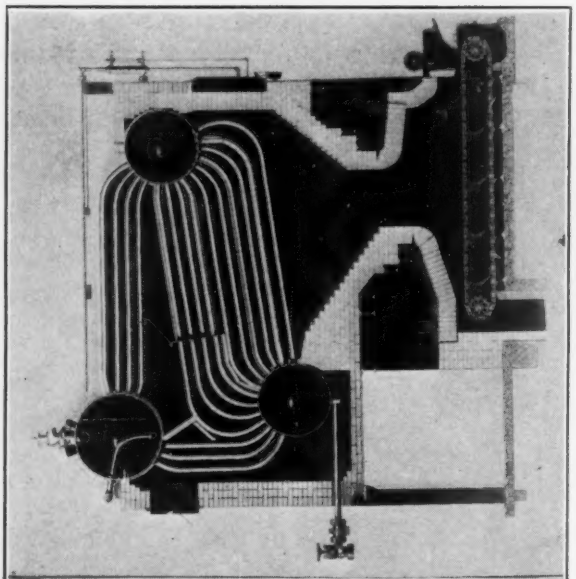

FIG. 12.—Modern water-tube boiler, chain-grate stoker, and refractory furnace for ratings up to 50,000 lb. of steam per hour at 300 lb. pressure.

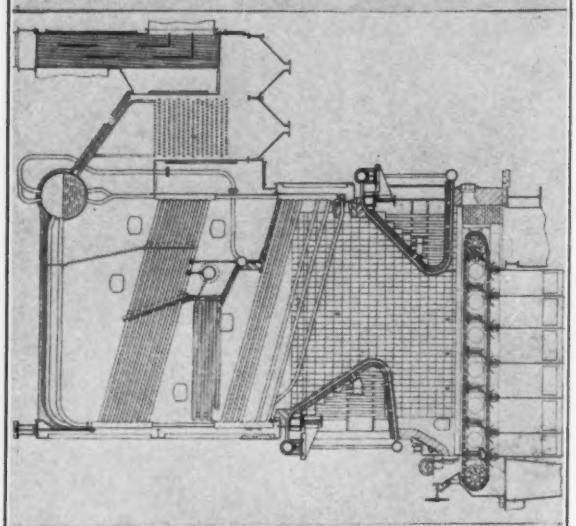

FIG. 11.—Chain-grate stoker with water-cooled walls and arches (present day).

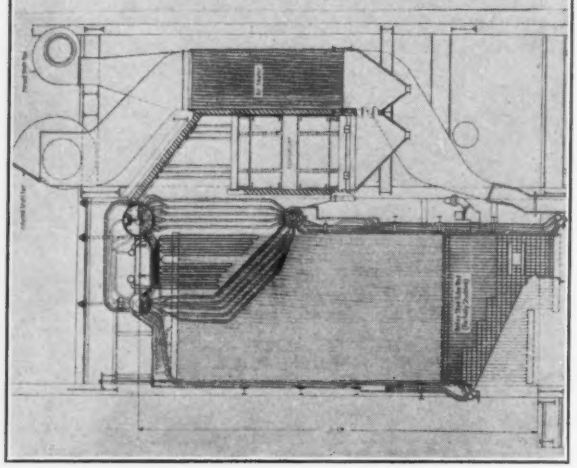

FIG. 10.—Underfeed stoker with water-cooled furnace, 1937 (Delray Station, Detroit Edison Co.).

tory exposed any place in this or other similar furnaces is a vulnerable spot and is a source of outage and maintenance. The ash in this furnace is molten and runs out at the bottom as a liquid at all but very low ratings.

In 1926, other developments began with slag-tap furnaces, a later model of which is shown in Fig. 16. This furnace is completely water-cooled, including the floor and all walls up to or beyond the bottom boiler tubes. The type of water cooling best suited for the floor and the lower part of this furnace is the fully studded construction shown in the bottom portion of Fig. 28. The smooth cast-iron blocks used in the upper part of the furnace are shown in the lower portion of Fig. 27.

There is more or less pyrites in all coal and, being hard to pulverize, it is usually coarser than the coal itself. The sulfur in the pyrites is oxidized and the remainder reduced to FeS or Fe and becomes buried under the molten slag away from any possible oxidizing agent. The present trend is toward continuous slag-tap or slag-drip furnaces, where the slag pool does not form. The pyrites is completely oxidized as it has no pool of slag into which it may become buried.

Figure 17 shows a late design of pulverized coal-fired furnace for coal having an ash of 2800°F fusing temperature. It has a capacity of 375,000 pounds of steam per hour at 1375 pounds pressure and 900°F. The fully studded tubes on the side walls opposite the burner aid in maintaining ignition at low rates and protecting the wall tubes from too high a rate of heat input at high ratings.

During the recent depression very few large boilers were installed. Among those started in 1935 were two like Fig. 18, each having a capacity of 600,000 pounds of steam per hour. This boiler has a two-stage furnace. The coal is burned in the slag-tap section and the gases pass through the spaced tubes, protected with full studs, and enter the boiler proper at the top of the second-stage furnace. The furnace slag screen shields a considerable portion of the radiant heat from the boiler tubes. This is described in a later type shown in Fig. 20.

Figure 19 shows furnace temperatures from the

first and second stages of the Richmond furnace of Fig. 18, as well as temperatures in the lower and upper parts of an open slag-tap furnace like Fig. 16 and Hell Gate, a larger open furnace similar to Fig. 16 but not shown here.

Figure 20 is undoubtedly the most advanced design of pulverized coal-fired furnaces yet developed. The boiler has a capacity of 575,000 pounds of steam per hour at 1450 pounds pressure and 935°F. The furnace is completely water cooled and is divided into two parts. The first stage of the furnace has six pulverized-coal burners, each having a coal-burning capacity sufficient to produce 120,000 pounds of steam per hour. When the maximum boiler output is being obtained, the fuel burned in this first-stage furnace exceeds 100,000 B.t.u. per cubic feet per hour.

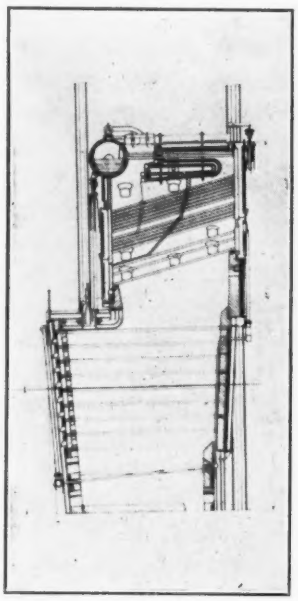

FIG. 13.—Pulverized-coal-fired furnace with air-cooled walls and a small amount of water cooling, 1923 (Springdale Station, West Penn Power Co.).

This first stage of the furnace has all walls, floor, and roof completely studded as shown in the lower portion of Fig. 28. In other words, it is a completely refractory-lined furnace. The refractory is plastic chrome ore about one inch thick and is held in place by being tamped between the studs, which are electrically welded to the tubes. The temperature in this part of the furnace is about 3100°F, which is conducive to rapid and complete combustion and a collection of a large percentage of the ash in molten form. The ash collected on the walls runs down and combines with that collected directly on the floor from the vertically downshot burners. This slag flows through the ports in the slag screen where the gas passes into the secondary furnace and up through the boiler, superheater, economizer, and air heater.

The secondary furnace is lined completely with smooth cast-iron blocks to prevent the accumulation of slag or ash and to cool the gases as much as possible before entering the boiler tubes. Some ash, which inevitably collects on the walls and the lower boiler tubes, falls, drips, or is blown off and passes down through the hopper bottom to a water seal and is removed by a sluice or clam shell.

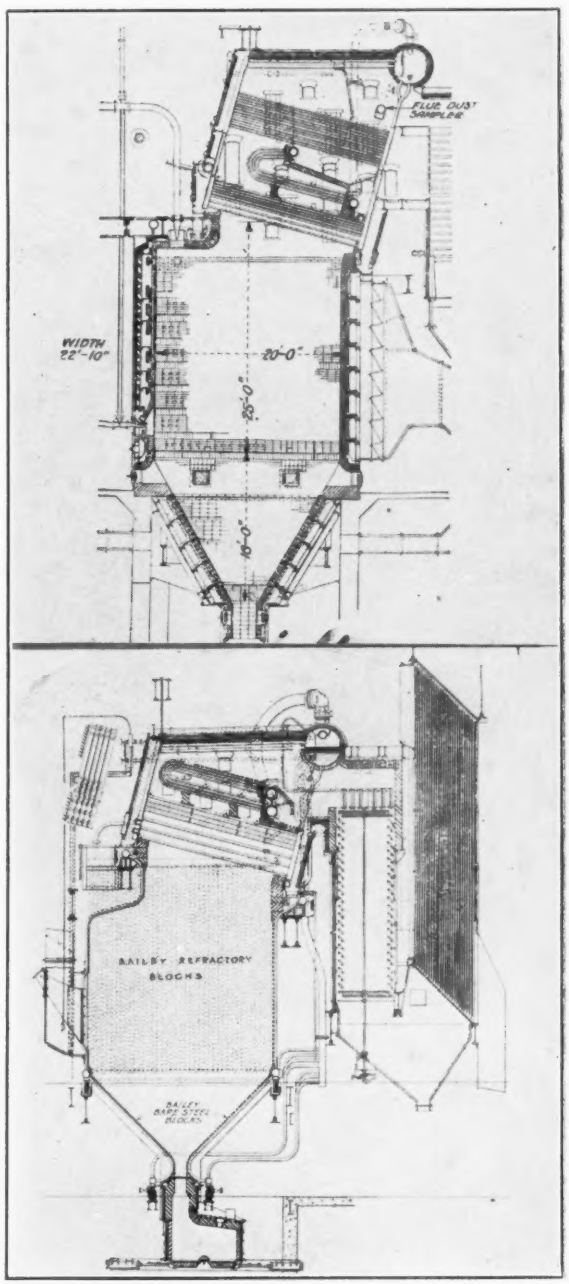

FIG. 14 (*top*).—Pulverized coal-fired furnace with air-cooled walls, 1926; some water cooling added later (Columbia Station, Columbia Gas & Electric Co.).
FIG. 15 (*bottom*).—Water-cooled furnace, pulverized coal-fired boiler, 1926 (Calumet Station, Commonwealth Edison Co.).

The radiant heat from the high-temperature,

first-stage furnace is shielded from ash particles approaching the boiler tubes by the division wall between the two parts of the furnace. The fly ash or slag particles being carried by the gases up through the second-stage furnace radiate heat as solid bodies through the nearly transparent hotter gases to the water-cooled walls, so the fly ash particles enter the tube bank at a lower temperature than that of the gas surrounding them and at a low enough temperature that their clogging of the gas passages between the tubes is greatly minimized. This boiler is just being started up and test data have not been obtained. It is believed that the temperature entering the boiler tubes is cooler than the corresponding furnace temperature shown in Fig. 18, although the rate of combustion per cubic foot is considerably higher in furnace of Fig. 20 than in furnace of Fig. 18.

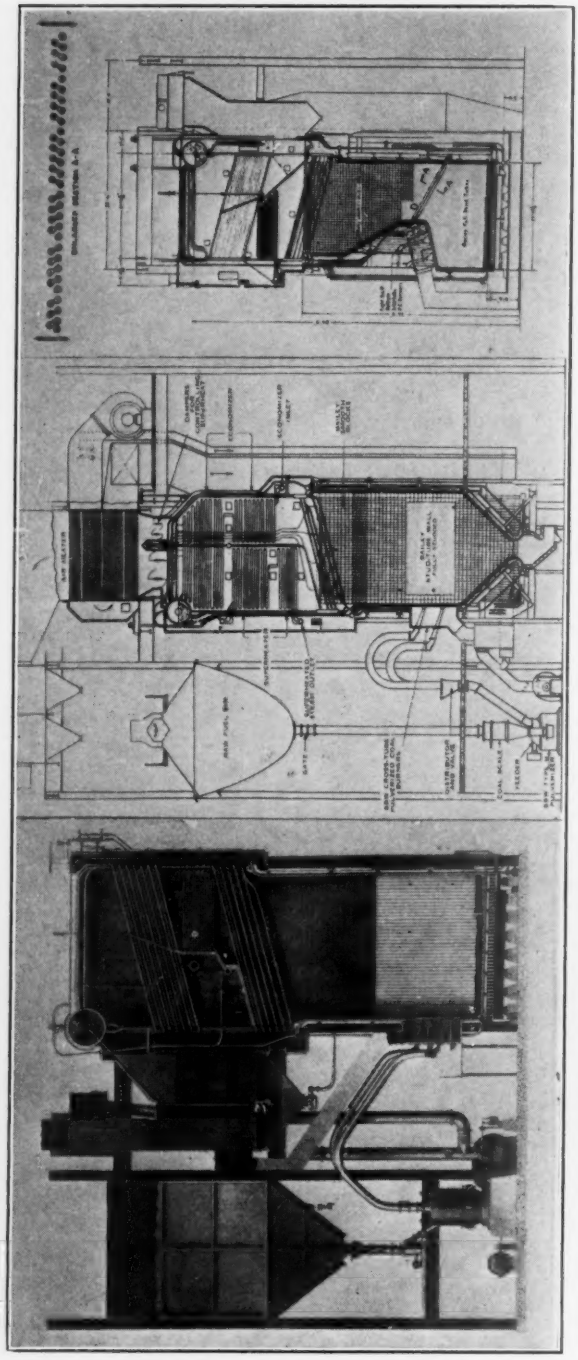

FIG. 16.—Pulverized-coal-fired water-cooled slag-tap furnace, 1935.

FIG. 17.—Water-cooled pulverized-coal-fired furnace, 1937 (Millers Ford Station, Dayton Power & Light Co.).

FIG. 18.—Pulverized-coal-fired water-cooled two-stage slag-tap furnace, 1935 (Richmond Station, Philadelphia Electric Co.).

Not all boilers are as large as those just described, and there is need for many boilers to burn pulverized coal, oil, or gas and to produce steam at rates from 20,000 to 200,000 pounds per hour at pressures up to 900 pounds. Such a boiler is shown in Fig. 21, the elevation in Fig. 22, and a plan view in Fig. 23. This boiler has three brick walls and a suspended refractory arch over the superheater; also the second and the third passes, if the gases are taken out through the back wall.

The furnace is water cooled on the side and roof with partially studded tubes. The floor is water cooled and covered with smooth iron blocks when burning coal and with brick when burning oil or gas. The burner wall is first-quality fire brick, except when burning low-fusing ash coal; then it is cooled with widely spaced tubes as shown in front of the back wall.

The back wall is refractory with bare tubes in front protecting the refractory to some extent. With low-fusing ash coal and higher ratings, this spacing of tubes is not sufficient protection and either closely spaced tubes, partially studded tubes, or cast-iron blocks are required. The partition wall between the furnace and the boiler is partially studded as shown in Fig. 23 and more clearly in Fig. 24. A boiler of this type burning pulverized coal is shown in Fig. 25 just as it came out of service with some loose ash nodules or honeycomb hanging from the partial stud walls near the burner end of the furnace.

This type of boiler and furnace arrangement is

particularly free from slagging within the boiler tubes in the first pass, partly because there is sufficient cooling for a furnace of this size and also because the flame near the burner can not radiate directly into the first-pass boiler-tube bank, owing to the direction of flow turning 90° and because it is at the far end of the furnace away from the burners.

The foregoing illustrations show the trend in furnace development from the original completely water-cooled furnace, of which the locomotive is typical, to small refractory furnaces which prevailed up until about 1916. From this date, the boilers were set higher, and larger refractory furnaces, some with air cooling, prevailed. The refractory maintenance problem was so great and boiler slagging held down outputs to such an extent that water cooling grew rapidly from about 1923 or 1924 until today it is general for all but the smaller boilers.

Some of the earlier water-cooling constructions as shown in Fig. 26 were found to be inadequate, and tubes were placed closer together. Another design incorporated welded fins, filling the space between the tubes so that insulating material was used only back of the tubes. Another variation of Fig. 26 is to place the tubes close together with about $^1/_8$-inch clearance.

Figure 27 shows block-covered tubes which have been used throughout the world more extensively than any other one kind. The smooth cast-iron block is suitable for fuel-bed clinker zones, hopper bottoms, and where the maximum of cooling and freedom from ash adherence is desired.

The rough block is suitable where a hotter furnace is desired because the ash will accumulate and will simulate the refractory-faced block shown in the upper portion of Fig. 27. The refractory is a fired tile cast into the iron forming the block. Another form has a fired refractory cemented into a cast-iron block so that no iron is exposed to the furnace. The rough block and the refractory-faced blocks are being used less because their purpose is being well served by the stud-tube water-cooled furnace construction shown in Fig. 28, which meets all requirements not met by the bare cast-iron blocks.

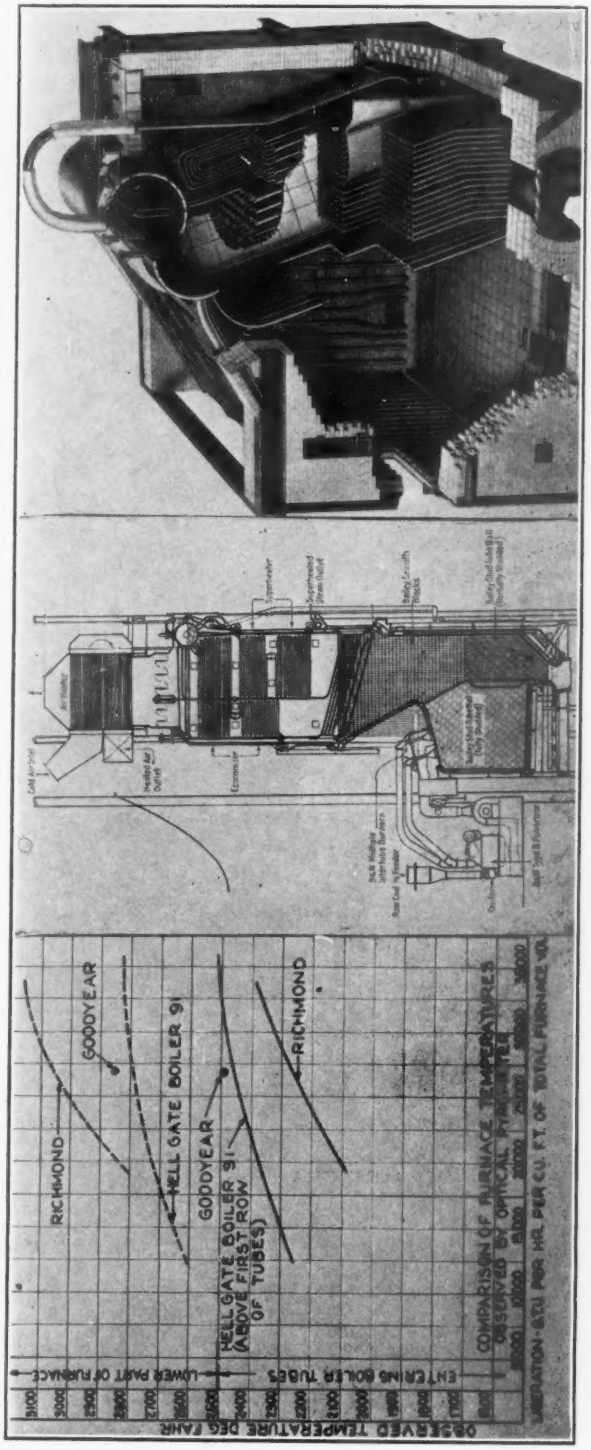

FIG. 19.—Furnace temperatures showing contrast between two-stage furnace at Richmond Station (Fig. 18) and other open furnaces similar to Fig. 16.

FIG. 20.—Pulverized-coal-fired two-stage slag-tap furnace, 1937 (Springdale Station, West Penn Power Co.).

FIG. 21.—Modern pulverized-coal, oil, or gas-fired integral furnace with partial water cooling suitable for 200,000 lb. of steam per hour at 900 lb. pressure.

The full stud with chrome-ore refractory meets the most exacting requirements of the first stage of the furnace of Figs. 18 and 20. A refractory-covered wall is better for this condition than are closely spaced tubes. The refractory helps to keep a hotter furnace, aids combustion at low ratings, taps slag better at all ratings, collects more ash within the furnace, and diminishes the rate of heat input per square foot of water wall so

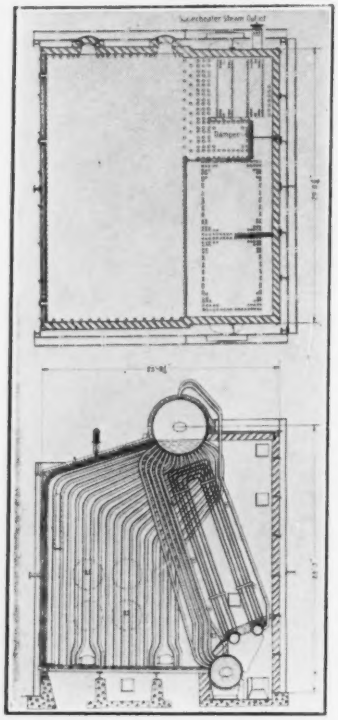

FIG. 22.—Integral furnace boiler (elevation of Fig. 21).

that a slight deviation in feed-water treatment may not cause loss of tubes. The partial stud construction is ideal for furnaces or portions of furnaces where more cooling is desired.

Refractories will be used more in surfacing the hotter portions of water walls. Refractories and insulating brick will continue to be used in the boiler settings above the water-wall area.

It might seem that natural gas and oil-fired boilers could continue with refractory furnaces, but even here water cooling has been in demand. Boiler furnaces, as shown in Fig. 29, were commonly used in the 1920's and still are to some extent, with heat liberations up to 50,000 B.t.u. per cubic foot or more. Quick changes in rate of steaming cause spalling, and the ash in bunker C oil today causes wastage of refractories.

More recent installations like Fig. 30 are similar, but those with stud tubes as in Figs. 16 and 28 are more popular.

In the marine field, boilers like Fig. 31 inclose a fair portion of the furnace area, thereby reducing the amount of refractory walls and, by increasing the "fraction cold," help prolong the life of the refractory as used. Rates of combustion in such furnaces reach as high as 300,000 B.t.u. per cubic foot per hour.

Water cooling again answers a problem of lightweight high-duty boilers of the steamotive type for railway, marine, and readily portable stationary use. Figure 32 is such a boiler adapted to burn either oil or pulverized coal up to 250,000 B.t.u. per cubic foot. This boiler has no induced-draft fan, but only a forced-draft fan so that the furnace is operating at temperatures above 2700°F under a pressure of 40 to 50 inches of water.

Figure 33 is a plot of the gas temperature through such a furnace and boiler, together with the segregation characteristics of the ash collected from the walls of the furnace and open passes.

Figure 34 shows an adaptation of water cooling of the full stud type to a black-liquor furnace and smelter, where fuel with approximately 30% combustible, 25% ash and smelt, and 45% water is burned directly, and the smelt is recovered as a molten stream 2 to 3 inches in diameter continuously. Other forms of black-liquor recovery furnaces have used soapstone as the refractory best suited, but their maintenance was high.

Waste-heat boilers offer no particularly difficult refractory problems because of the low temperatures which usually prevail. Fire-tube boilers, however, are being used extensively for waste heat, so that no refractory setting is required beyond the gas ducts or flues bringing the gas to and taking it from the tube bank.

IV. Summary

The generation of steam can be economically produced from a wide variety of fuels, including all kinds of coal, lignite, waste refuse, etc.

The ash, which usually forms slag in the furnace when such fuel is burned, is an important factor in establishing the trend in furnace design or, if the design is not adequate, it limits the rate of combustion, and, therefore, the output of the unit.

Many small boilers burning fuel with stokers, as well as oil or gas, continue to use reasonably sized refractory furnaces to a great extent.

The larger boilers for industrial use, as well as central stations, have adapted quite generally water-cooled furnaces of some kind or another in a greater or less degree, depending upon the nature of the ash, the economics of high rating, and many other factors.

In certain districts the trend is to burn natural gas or oil if it is the most efficient fuel, but where coal is the economic fuel the trend is toward using it in pulverized form more than with stokers.

Properly applied water cooling adds to the reliability of the furnace, reducing maintenance and outage charges, and enables a greater degree of variation in load at higher ratings as far as the furnace walls themselves are concerned.

Water cooling properly applied assists in the discharge of ash from the furnace, whether dry, semidry, or slag tap.

Cooling of the gases after they leave the combustion zone is essential to prevent slagging and clogging of the boiler-tube banks, and the resulting extended reduction in areas of gas passages and restriction of stream output.

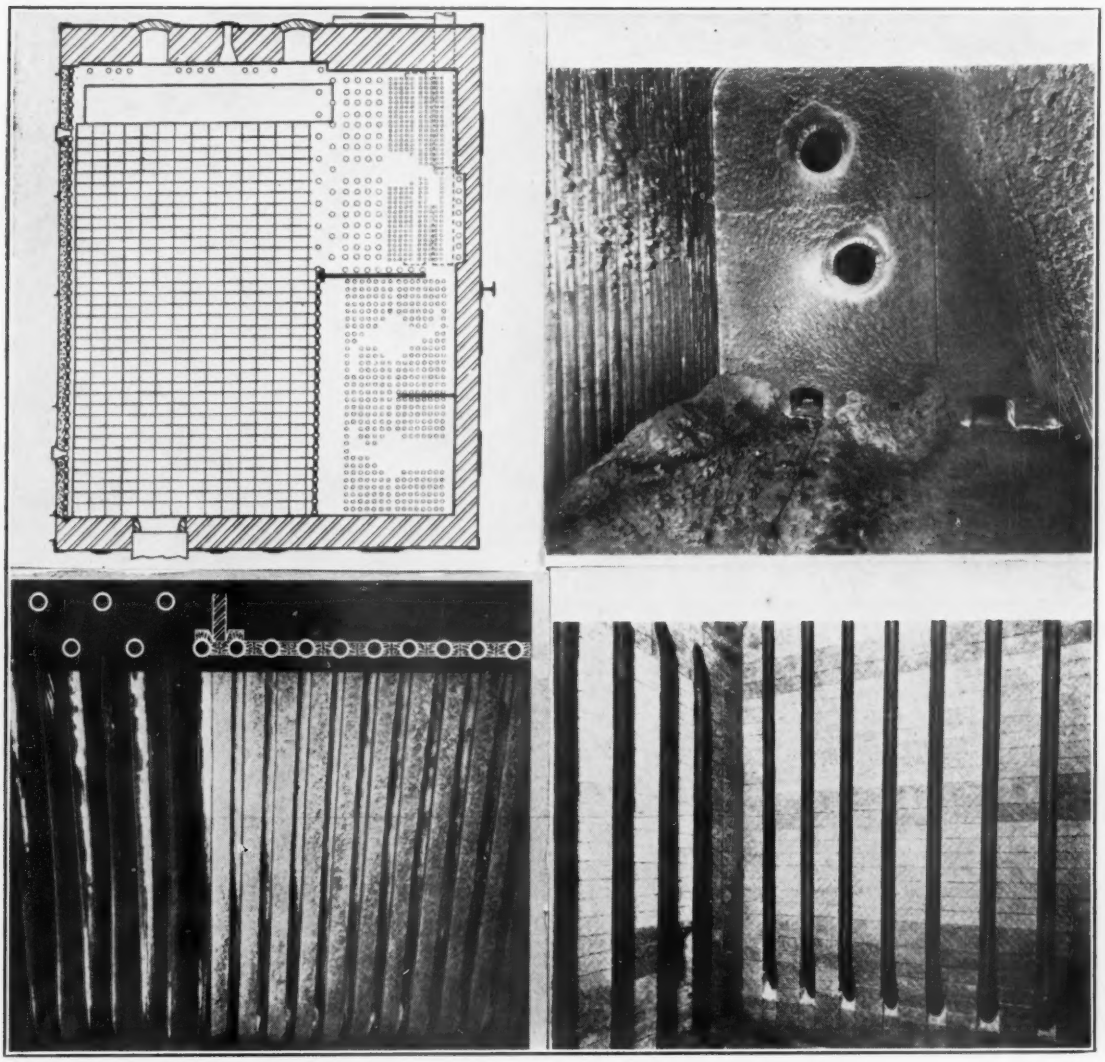

FIG. 23 (*top, left*).—Integral furnace boiler (floor plan of Fig. 21).
FIG. 24 (*bottom, left*).—Integral furnace boiler tube-bank and stud-tube partition wall between furnace and boiler passes.
FIG. 25 (*top, right*).—Integral furnace boiler furnace interior.
FIG. 26 (*bottom, right*).—Water-cooling furnace construction (tube and tile construction).

The addition of water cooling to generating units usually reduces the total cost, increases the overall efficiency and, with certain forms of water cooling, reduces the weight and space required.

burned in conjunction with base fuels, a serious refractory problem is avoided by the use of proper water cooling.

Water cooling should be surfaced with suitable

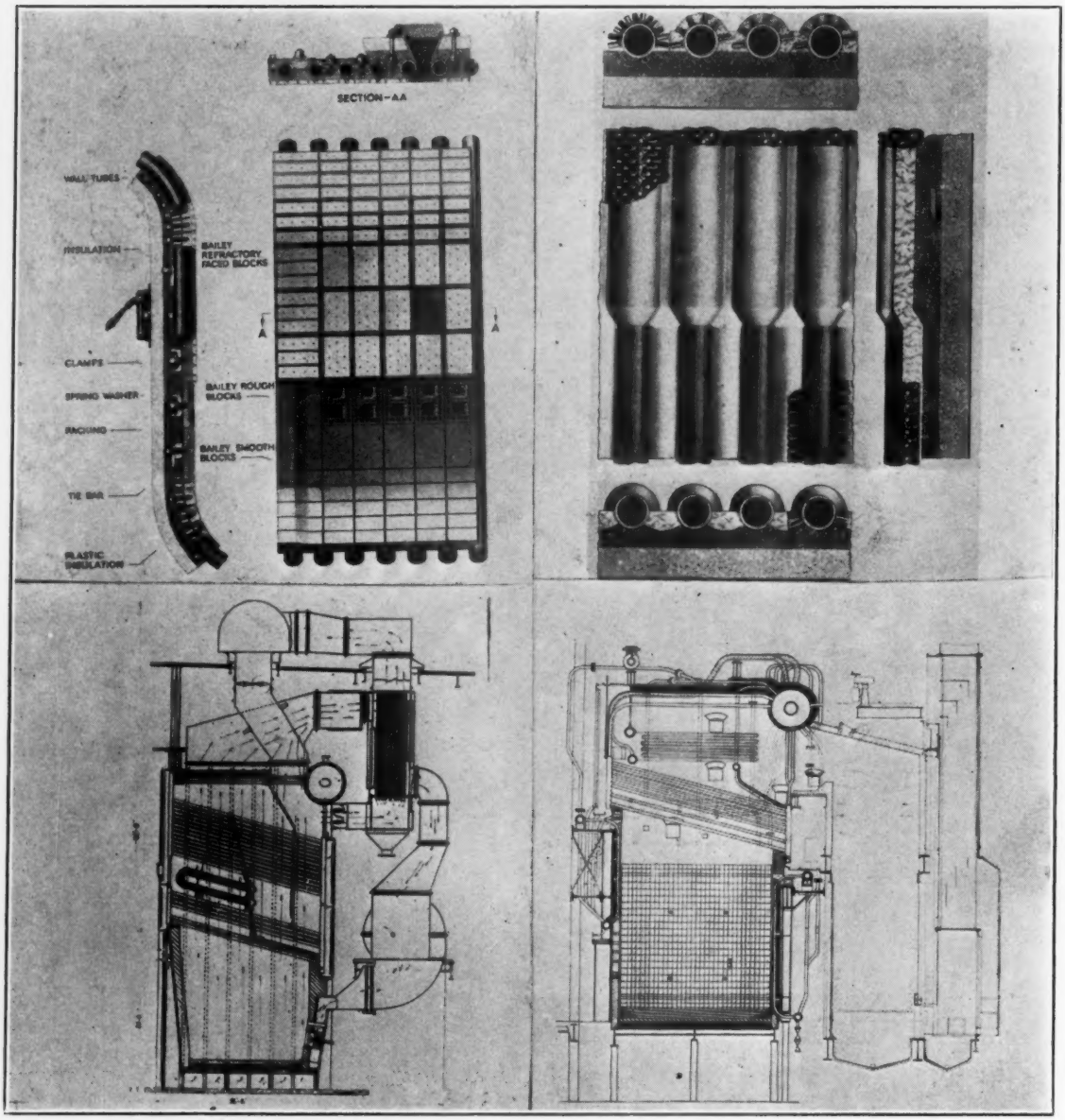

FIG. 27 (*top, left*).—Water-cooling furnace construction (Bailey blocks).
FIG. 28 (*top, right*).—Water-cooling furnace construction (stud tubes).
FIG. 29 (*bottom, left*).—Oil-fired furnace with air-cooled refractory walls, 1923 (Houston Light & Power Co.).
FIG. 30 (*bottom, right*).—Oil-fired, water-cooled furnace, 1931 (Pacific Gas & Electric Co., San Francisco).

With better burning equipment and water-cooled walls, smaller furnaces can be used, thereby making a large saving in space, weight, and cost.

In industrial plants where waste fuels are

refractory in the high-temperature combustion zone with all fuels, and it is absolutely essential with certain low-grade fuels which can not be burned in a furnace with too low a temperature.

Water cooling can be adapted to a steam generating unit without increasing the total fuel required for a given steam output and is in the direction of increased thermal efficiency.

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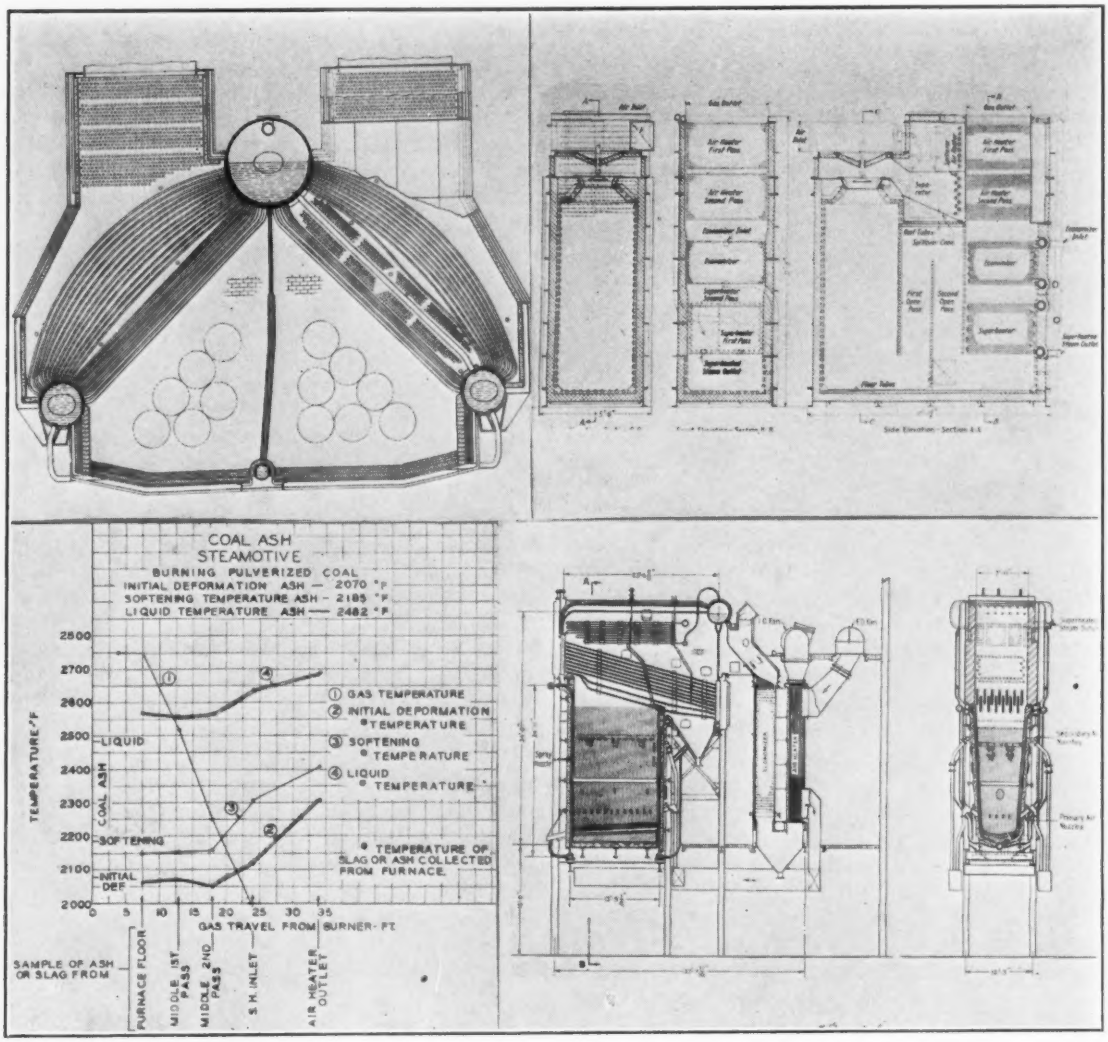

FIG. 31 (*top, left*).—Marine boiler with water-cooled division wall.
FIG. 32 (*top, right*).—Steamotive boiler forced circulation for oil, gas, or coal firing, 1937.
FIG. 33 (*bottom, left*).—Gas temperatures and slag characteristics from boiler of Fig. 32.
FIG. 34 (*bottom, right*).—Recovery unit for black liquor with water-cooled furnace.

THE PRESIDENT'S PAGE

STANDARDS

"Standard: Any measure of extent, quantity, quality, or value established by law or by general usage and consent."

To make a standard effective, formal adoption is not always necessary, nor does it have to be associated with a public law and backed up by the machinery of legal enforcement. Why then do we accept the cited standard so universally? Simply because we know it was prepared by men of scholarship who had devoted years to the study of usage and who acted in a completely disinterested way in reaching their final conclusion. No better foundation can be had for any standard, in any field of activity.

In the foregoing statement the emphasis is on the phrase "established by general usage and consent" rather than "established by law." It may readily be granted that the process is inefficient. It results in illogicalities and in compromises determined by commercial interest. It may even be influenced by politics (see *Bull. Amer. Ceram. Soc.*, **16** [12] 478 (1937)). A dictatorship could do the job so much better (in theory). The dictator or his appointed representative, assumed to be possessed of more complete information, superior wisdom, and greater disinterestedness than any democratically assembled committee, can review the case dispassionately and render a decision that is logically and technically consistent with all the decisions that have preceded. But whatever may be thought of the theory, we in the democratic countries are up against democratic methods in making industrial progress, and we may as well adapt ourselves to them.

Since the bringing together of well-informed and experienced individuals is the first essential step in setting up standards, the technical societies associated with an industry are the natural source of the industry's standards. Good intentions, however, are not enough. Quite elaborate organizing machinery is necessary if the results are to be acceptable. This is no hypothesis, but a conclusion from experience, including the experience of this Society. It takes a permanent organization, well supported with funds and properly geared, to initiate, discuss, criticize, project, revise, re-project, re-revise, promulgate, publish, advertise, and defend standards. The organization must be elaborate enough and elastic enough that the death, the disability, or even the slackening of activity of any one member will not interfere seriously with the progress of standardization along the line with which that individual is concerned.*

Two organizations that are built up in just this way are the American Society for Testing Materials and the American Standards Association. In principle, the first of these is concerned with standard methods of testing only, but it is impossible to separate testing completely from other forms of standardization. The A.S.T.M. does not hesitate, for example, to set up standard definitions of technical terms, after full publicity and full opportunity for criticism. This is not the academic activity that it might at first seem, for patent offices, courts, and rate-fixing agencies have to deal in words whose meaning should be unequivocal, else each decision begets further argument in a geometrically increasing series.

The American Standards Association is a younger organization, a voluntary association of individuals and groups interested in standardization, and not interested just to be helpful, either, but interested for sound economic reasons of self-preservation, defense, or aggrandizement. The Government is a necessary party to this activity, not as umpire, referee, or policeman, but as a consumer and as a defender of the State against outside enemies.

With its existing resources and forms of operation, the American Ceramic Society is not well geared for the standardization of ceramic products or tests. This is purely a personal opinion, not an official announcement of policy. Yet I have no hesitation in saying that the Society contains in its unified membership the best qualified scientists, educators, technologists, and engineers to be found associated with ceramic industry anywhere in the world. It should therefore be our policy to encourage our members, either as individuals or as small committees, to be prepared to furnish assistance in any ceramic standardization that is under way. Committee C-8 on Refractories, A.S.T.M., is in fact made up almost solidly of our own members, and has even established the custom of holding its principal meeting of the year at the time and place of the Annual Meeting of the American Ceramic Society.

We need not be satisfied with this somewhat passive attitude. There are projects of ceramic standardization that need to be initiated. There are standardizing committees in A.S.T.M., A.S.A., and other organizations, in which ceramic advice and experience are urgently wanted if a result satisfactory to all is to be attained. Furthermore, the bringing together of diverse and apparently unrelated interests, bonded together as this Society is by common use of earthy raw materials and common employment of high temperatures in manufacturing, has been found to result in unexpected and useful modifications of standards. We should, therefore, see to it that our voice is heard in these places. J. W. Whittemore, Chairman of our General Committee on Standards, has been making a survey of these opportunities and responsibilities and I trust that this activity will be supported and continued.

Modesty and self-effacement may have their place, but not on a Standards Committee.

—ROBERT B. SOSMAN

*The best recent statement that I have seen on the principles guiding industrial standardization is by F. B. Jewett, President of the Bell Telephone Laborotories, in *Industrial Standardization and Commercial Standards Monthly*, **8**, 323–30 (Dec., 1937).

ACTIVITIES OF THE SOCIETY

NOMINATING COMMITTEE REPORT

The Committee on Nominations of the American Ceramic Society has submitted the names of the following persons to be ballotted on for the 1938–1939 officers of the Society:

For President: V. V. KELSEY, 1403 Trenton Trust Bldg., Trenton, N. J.

For Vice-President: A. I. ANDREWS, University of Illinois, Urbana, Ill.

For Treasurer: C. FORREST TEFFT, The Claycraft Co., Columbus, Ohio.

Victor V. Kelsey for President

C. Forrest Tefft for Treasurer

A. I. ANDREWS NOMINATED FOR VICE-PRESIDENT

Andrew Irving Andrews was born at Baraboo, Wis., June 10, 1895; he attended public schools at Oshkosh, Wis., was graduated from the Oshkosh High School in 1915, and in September of that year he entered the University of Wisconsin. He served as ensign in the U. S. Naval Reserve Force from June, 1918, to July, 1919, and then reëntered the University of Wisconsin. In 1920, he received his B.S. degree in chemistry at the University of Wisconsin; he was graduate assistant in analytical chemistry at that University and in October, 1921, he received his M.S. degree. In September, 1922, he entered Ohio State University in the department of industrial chemistry and was assistant in general chemistry. He studied under a fellowship of the U. S. Bureau of Mines Ceramic Experiment Station, Ohio State University, in 1923, and in August, 1924, received his Ph.D. degree in industrial chemistry. His thesis topic was "Making of Dolomite Brick."

During the summer of 1924, Dr. Andrews did a full-time special research for the Bureau of Mines and the Dolomite Products Company.

In September, 1924, he became professor of ceramic engineering at Alfred University, also serving as consultant for the Dolomite Products Company during 1924 and 1925.

In September, 1925, he accepted a position as assistant professor of ceramic engineering at the University of Illinois. The summers of 1926 through 1928 were spent as follows: 1926, ceramic engineer for the Chicago Hardware Foundry Company; 1927, special coöperative research at the University of Illinois; 1928, consultant for the A. O. Smith Corporation and at the University of Illinois for a special coöperative research. He also wrote a book, Ceramic Tests and Calculations.

In 1928 he became associate professor of ceramic engineering at the University of Illinois, and in 1933 became professor of ceramic engineering. During the summers, from 1929 through 1932, he was full-time research consultant for the A. O. Smith Corporation.

In 1934 Dr. Andrews wrote a book, Enamels; in the summer of 1935 he was full-time consultant for the Titanium Alloy Manufacturing Company and also for the R. & H. Chemical Division of the E. I. du Pont de Nemours & Company; during the summers of 1936 and 1937, he engaged in full-time research for du Pont. During the school year he has acted as consultant, principally on porcelain enameling, for many companies.

A. I. Andrews for Vice-President

At present, Dr. Andrews is professor of ceramic engineering at the University of Illinois and is Chairman of the Committee on Definitions of the Porcelain Enamel Institute.

During his teaching experience, he has presented the following courses: ceramic bodies, ceramic glazes and glasses, porcelain enamels, structural clay products, pyrochemical problems, chemistry of the silicates, ceramic pyrometry, cements, limes and plasters, drying and firing, ceramic calculations, general chemistry, analytical qualitative chemistry, analytical quantitative chemistry, chemical preparations, and mineralogy and geology.

Dr. Andrews became a member of the American Ceramic Society in 1924, and in 1933 served as Chairman of the Enamel Division. He is a Fellow of the American Ceramic Society.

Publications of A. I. Andrews

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G. L. Clark, and H. W. Alexander, "Progress Report on the Determination of the Compounds Causing Opacity in Vitreous Enamels," *Jour. Amer. Ceram. Soc.*, **14** [9] 634–39 (1931).
and D. G. Bennett, "A Systematic Study of Sheet-Iron Cover Enamels and a Method for Improving Acid Resistance, *ibid.*, **14** [8] 590–602 (1931).
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and R. K. Smith, "The Thermal Expansion of Sheet-Iron Ground-Coat Enamels," *ibid.*, **16** [7] 328–37 (1933).
and R. E. Mullady, "Further Data on Reboiling of Sheet-Iron Ground-Coat Enamels," *ibid.*, **17** [10] 288–91 (1934).
and E. G. Porst, "Effect of Water Hardness on Vitreous Enamel Suspensions," *ibid.*, **17** [10] 292–97 (1934).

* Dr. Andrews is the senior author for these papers.

CORPORATION MEMBERS ARE ESSENTIAL TO CONTINUANCE OF THIS COÖPERATIVE PROMOTION OF CERAMIC ART AND SCIENCE

"Substantial and Progressive" Characterizes The American Ceramic Society

As Shown By

(1) Member Activities

(2) Member Support

(3) Meeting Programs

Fortieth Annual Meeting

Programs for eight half-day and two night sessions are over-flowing with papers that are above the usual qualtity. For substantiality in ceramic science, this will be a record Meeting.

Membership Record

January always brings resignations, but fewer in this than in any previous year, and these resignations have been offset by new members joining.

MEMBERSHIP RECORD

Date of Record	Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
	Personal	Corporation				
December 20, 1936	1452	196				
December 22, 1937	1713	220	12	523	220	2688
January 22, 1938	1712	220	12	530	220	2694

NEW MEMBERS

Corporation

TWYFORD, LIMITED, Cliffe Vale Potteries, Stoke-on-Trent, England.

UNION ELECTRICAL PORCELAIN WORKS, INC., F. W. Van Orden (voter), P. O. Box 762, Trenton, N. J.

Personal

*BEINLICH, ALFRED W., House 109, Village 2, P. O. Box 1412, Wilson Dam, Ala.; ceramic aide, Tennessee Valley Authority.

BLACKBURN, ANDREW R., 2631 S. 9th St., Ironton, Ohio; ceramic engineer, Ironton Firebrick Co.

BRAYKOVICH, ANDREW, Box 48, West Pittsburgh, Pa.; development manager, Universal Sanitary Mfg. Co.

CAMPBELL, VAN E., 363 Highland Ave., Wadsworth, Ohio; Ohio Brass Co.

CHAFFEE, CLARE S., 1237 Vancouver St., Burlingame, Calif.

CURTIS, A. B., 1530 Builders Exchange Bldg., 45 Prospect Ave., N. W., Cleveland, Ohio; insulation manager, Johns-Manville Sales Corp. (formerly in name of J. W. Blemker).

GREEN, ARNOLD T., Mellor Laboratories, Stoke-on-Trent, England; director of research.

HORELICK, JULIUS, 3702 Eldorado Ave., Baltimore, Md.; control engineer, Standard Gas Equipment Corp.

JAEGER, VICTOR, Great Lakes Steel Corp., Tecumseh Rd., Ecorse, Detroit, Mich.

JEFFERY, BENJAMIN D., 315 Hendrie Blvd., Royal Oak, Mich.; Champion Spark Plug Co.

LONG, GEORGE R., Frigidaire Div., General Motors Corp., Dayton, Ohio (formerly in name of F. L. Meacham).

PECK, J. CLAIR, 59 Boylston, Bradford, Pa.; assistant superintendent, Hanley Co.

ROBERTSON, CAMPBELL, E. I. du Pont de Nemours & Co., Wilmington, Del. (formerly in name of J. H. Young).

SMITH, HUBERT, Great Lakes Steel Corp., Tecumseh Rd., Ecorse, Detroit, Mich.

STAPLEFORD, GEORGE H., 117 Thompson Ave., East Liverpool, Ohio; assistant art director, Homer Laughlin China Co.

TAYLOR, JOHN B., 2216 Valley Vista Rd., Louisville, Ky.; chemist, Louisville Pottery Co.

WALKER, LEANDER H., Town Line Rd., Coldwater, N. Y.; ceramic engineer, The Pfaudler Co.

WIESE, GEORGE I., 5003 Schesty Heights Ave., Baltimore, Md.; enamel plant superintendent, Standard Gas Equipment Corp.

WILLIAMS, LAURENCE L., 515 N. Wolfe St., Baltimore, Md.; occupational instructor, Johns Hopkins Hospital.

Student

AMERO, JOHN J., University of North Carolina.

BARBOUR, DAVID J., Rutgers University.

DAY, FRANK, JR., University of Pittsburgh.

LANNES, EUGENE M., Ohio State University.

SHOEMAKER, MONTGOMERY J., New York State College of Ceramics.

SPIGEL, PHILIP, New York State College of Ceramics.

UPTON, LEE O., Pennsylvania State College.

* Indicates former member of the Society rejoining for 1938.

MEMBERSHIP WORKERS' RECORD

Corporation

A. C. Gerber	1	Office	1

Personal

C. E. Bales	1	B. A. Jeffery	1
J. R. Beam	1	Gordon R. Pole	1
F. H. Clews	1	Bryan A. Rice	1
Conrad Given	2	W. H. Russell	1
E. C. Greenstreet	2	R. B. Sosman	1
		Office	4

Student

S. J. Brooks	1	E. C. Henry	1
R. M. Campbell	1	M. E. Holmes	1
George T. Faust	1	Alexander Silverman	1
A. F. Greaves-Walker	1	**Grand Total**	**25**

ROSTER CHANGES DURING JANUARY*

Personal

BLODGETT, MALCOLM, 40 Court St., Boston, Mass. (Woburn, Mass.)

MASSEY, CRAWFORD, General Delivery, Hollydale, Calif. (Downey, Calif.)

METZGER, A. J., 1181 E. Livingston Ave., Columbus, Ohio. (Austin, Texas)

MORGAN, WILLARD L., 72 Massasoit Ave., Edgewood, R. I. (Providence, R. I.)

SKLAR, SAMUEL B., 1331 Lincoln Place, Brooklyn, N. Y. (New York, N. Y.)

STAFFORD, W. L., Johns-Manville Corp., Manville, N. J. (East Liverpool, Ohio)

SUTTON, W. J., P. O. Box 594, Alfred, N. Y. (Foochow, China)

WALSH, DONALD E., Consolidated Feldspar Corp., East Liverpool, Ohio. (Kingman, Ariz.)

Student

GREEN, ROBERT L., Massachusetts Institute of Technology Dormitories, Cambridge, Mass. (Duquesne, Pa.)

MULQUEENY, THOMAS J., Western Union Telegraph Co., Edwardsville, Ill. (Alton, Ill.)

* Address in parentheses is the former address.

Plan to Attend the Annual Meeting
New Orleans, La.
March 27–April 2, 1938

LOCAL SECTION AND STUDENT BRANCH NEWS

CHICAGO SECTION

A meeting of the Chicago Section was held on December 18, 1937, at the Bismarck Hotel, Chicago, with twenty-six members in attendance for the luncheon. The meeting was called to order by G. G. Hanson, *Chairman*. Herbert Kaeppel, *Secretary*, reviewed the financial condition of the Section and showed a balance on hand of $307.65 as of May 1, 1937, the date on which he had left for California. It was pointed out to the group that some expenses had been incurred in connection with mailings and prizes for the annual golf tournament and the mailings for the current meeting, so that the present balance would be about $15.00 less than the amount shown.

It was unanimously decided to reappoint the incumbent group of advisers to the Ceramic Department of the University of Illinois, namely:

JOSEPH WRIGHT, Owens-Illinois Glass Co.
WILLIAM SCHLAKE, President, Illinois Brick Co.
E. H. VAN SCHOICK, President, Chicago Retort & Fire Brick Co.
FRED L. STEINHOFF, Vice-President, Industrial Publications, Inc.
FRANK E. HODEK, JR., General Manager, General Porcelain Enameling & Mfg. Co.

The next matter up for discussion was the 1939 Annual Meeting. This brought out a great deal of discussion from the members, all of whom seemed to feel that Chicago would be a timely and practical place for the 1939 Meeting. It was also felt that the Board of Trustees would look favorably on the selection of Chicago as its guest city for that Meeting. After some discussion, the Chicago Section unanimously voted in favor of Chicago, and instructed the Secretary to extend an invitation to the General Secretary and Board of Trustees, individually and collectively, in conjunction with the Chicago District Enamelers Club, which had already voted favorably upon the selection. It was agreed that the work of the Annual Meeting, if held in Chicago, should be evenly divided between the Chicago Section and the Chicago District Enamelers Club. An equal division of expense was also decided upon. In answer to questions by some of the members, the opinion was given that the Board of Trustees would probably disapprove of any large exhibits in hotel lobbies by equipment and materials suppliers; but it was pointed out that such exhibits might be set up in rooms and suites.

The annual election of officers was the next piece of business, and the following were elected to serve the Chicago Section in 1938:

Chairman: ALBERT L. VODICKA, Aetna Porcelain Enameling Co., Chicago
Vice-Chairman: RUDYARD PORTER, Carnegie-Illinois Steel Co., Chicago
Secretary-Treasurer: REXFORD NEWCOMB, JR., Industrial Publications, Inc., Chicago

After this business had been taken care of, the speaker, H. V. Kaeppel, was presented. Mr. Kaeppel of Industrial Publications gave a brief talk on his experiences in visiting ceramic plants of the various branches while on the West Coast. He cited the use of overall-colored glazes for pottery and the western practice of finishing wall and floor tile to very close tolerances while in the raw state. He remarked that nearly every home in southern California, even those for the poorer classes, contains some floor and wall tile, particulary for sink drain boards and floors in bathroom and kitchen. He also lauded the brick manufacturers for their excellent work in reviving the brick industry by means of active promotion of reinforced-brick masonry, after the disastrous results of the Long Beach earthquake.

After a number of questions had been answered by the speaker, the attention of the members was drawn to the forthcoming joint meeting of the Chicago Sections of the American Ceramic Society and American Chemical Society, January 21, 1938, at the Stevens Hotel, at which time Alexander Silverman of the University of Pittsburgh was to speak on "Recent Developments in Glass."

—REXFORD NEWCOMB, JR., *Secretary-Treasurer*

MICHIGAN–NORTHWESTERN OHIO SECTION

At the December meeting of the Michigan-Northwestern Ohio Section, John D. Sullivan of Battelle Memorial Institute, Columbus, Ohio, gave an informal talk on "Trends in Refractories." Following his talk, he answered questions for nearly an hour. There were some automotive men in attendance who were greatly interested in this subject.

Following Mr. Sullivan's talk, Glenn Coley, representing the Engineering Society of Detroit, gave a short summary of "Reasons for Affiliating with E.S.D." The group voted unanimously to apply for membership, this application has been granted by the Board of Directors of E.S.D. Tom Place and F. H. Riddle have been appointed to membership on the affiliated council.

This meeting, held at the Intercollegiate Club in Detroit, was followed by the usual social after-meeting, which apparently seems to be enjoyed by our members.

—L. G. TAIT, *Secretary*

BALTIMORE-WASHINGTON SECTION

The Baltimore-Washington Section held its fall meeting at the Longfellow in Baltimore on December 11. Forty-three members and guests were in attendance.

A number of the members availed themselves of the opportunity to view a special exhibit of Italian ceramics at the Walters Art Gallery.

Dinner was served at 6:30 P.M., followed by a short business meeting with G. H. Spencer-Strong, *Chairman*, presiding. Announcement was made of the passing of Stephen Leech of Cheshire, England, and a resolution was passed to extend the sympathies of the Section to the family of Mr. Leech.

Following the business meeting, Ernest Cloos of the Geology Department of Johns Hopkins University spoke on "Some Recent Activities of the Maryland Geological Survey." During the course of his discussion, Dr. Cloos told of the various requests made by the public upon the Survey. He also described and compared field and laboratory methods of study and mentioned a number of practical applications in which these methods proved valuable.

—JAMES D. TETRICK, *Secretary-Treasurer*

PITTSBURGH SECTION

The Pittsburgh Section met on January 11 to hear Wm. P. Yant, Director of Research, Mine Safety Appliances Company, deliver an interesting talk on "Industrial Dust." All of those present enjoyed Mr. Yant's informal method of presenting his subject and were especially appreciative of his simple yet effective description of the disease, silicosis, and its cure and treatment.

The following men were elected officers of the Section for 1938–39.

Chairman: DWIGHT BENNETT, Mellon Institute
Vice-Chairman: W. C. RUECKEL, Koppers Company
Secretary: C. L. THOMPSON, Harbison-Walker Refractories Co.
Treasurer: J. W. HEPPLEWHITE, Edwin M. Knowles China Co.

—W. C. RUECKEL, *Secretary*

OHIO STATE UNIVERSITY STUDENT BRANCH

The regular monthly meeting of the Student Branch of the American Ceramic Society was held Wednesday, January 19, 1938, in Lord Hall, O.S.U.

This first meeting of the quarter was especially planned for sophomore ceramic engineers and for freshmen planning to enter ceramics or those who would be interested in learning more about what the field has to offer, its possibilities, etc. This subject was covered thoroughly by the professors of the Ceramic Department. Refreshments were served.

—JAMES WILLIS, *Secretary*

NOTES AND NEWS

COÖPERATIVE MINERAL RESEARCHES

U. S. Bureau of Mines and North Carolina Geological Survey

New uses for nonmetallic minerals found in North Carolina will be developed in a research project recently begun by the U. S. Bureau of Mines in its new Nonmetallic Minerals Experiment Station at College Park, Md., has been announced by State Geologist M. J. Bryson, chief of the Mineral Resources Division of the Department of Conservation and Development of North Carolina.

Not only will the U. S. Bureau of Mines try to develop new uses for the nonmetallic minerals, such as kaolin, kyanite, mica, talc, pyrophyllite, and spodumene, but it will also attempt to work out better methods for purifying these minerals at the mines, in order to reduce transportation costs. Perfection of better methods for reducing, calcining, or washing these minerals at the mines to remove the bulk of impurities will help both mine operators and manufacturers because transportation costs will be materially lowered.

WESTERN LECTURE TOUR OF ALEXANDER SILVERMAN

Alexander Silverman, Head of the Department of Chemistry in the University of Pittsburgh, delivered a series of lectures on glass during the week of January 17, 1938. On January 17, he lectured at the University of Iowa, Iowa City, on "A Survey of Glass Technology." The same lecture was repeated January 19 at Iowa State College in Ames, Iowa. On January 21, he lectured on "New Developments in Glass Manufacture" at a joint meeting of the American Chemical Society and the Chicago Local Section of the American Ceramic Society in Chicago, Ill.

NEW FELLOWSHIPS AT WESTINGHOUSE

Five post-doctorate fellowships for research in modern physics at the Westinghouse Research Laboratories in East Pittsburgh during 1938–1939 will be awarded this spring to young scientific workers, according to an announcement made by the Westinghouse Electric and Manufacturing Company. Appointments will be for one year and the fellows will be eligible for one reappointment. Five more fellows will be appointed the following year under a plan which provides ultimately an opportunity for ten physicists to continue their researches using the facilities of one of the nation's leading industrial laboratories.

"Westinghouse is deeply conscious of the debt which modern electrical industry owes to the fundamental science of physics on which it is built, and of the many advantages to a developing technology of close association with current advances in pure science," L. W. Chubb, director of the Westinghouse Research Laboratories, said in discussing the new fellowship plan. "In connection with plans for expanding our fundamental research in physics, it seemed to us that a very worth-while contribution could be made by establishing a group of fellowships for basic science work in the Company's research laboratories in East Pittsburgh."

Applications must be received by March 1, 1938, and awards will be announced early in April, 1938. Candidates are expected to propose a definite research problem within the field of the Laboratories' activities on which they plan to work. The work of the fellows will be under the general supervision of E. U. Condon, formerly of Princeton University, and recently appointed associate director of the Laboratories for the program of fundamental research.

PENNSYLVANIA STATE COLLEGE EXTENSION TRAINING NOW OFFERED IN 35 COUNTIES

Mineral Industries Extension Classes in 98 Centers

Four thousand three hundred and forty-seven students are enrolled in various courses offered by the extension division of the School of Mineral Industries at the Pennsylvania State College this year.

The greatest enrollment is found in the classes in mining. One thousand nine hundred and seven persons are enrolled in 93 classes taught in 59 centers located in 18 counties.

Classes in metallurgy closely follow those in mining in size. One thousand three hundred and ninety-one persons are enrolled in the 48 metallurgical classes which are located in 15 centers in 11 counties. Petroleum and natural gas engineering is third in enrollment with 802 students in 34 classes located in 15 centers which are distributed among 10 counties. **Two hundred and forty-seven are enrolled in nine ceramics classes, each of which represents a different center and county.**

One hundred and sixty-eight teachers are employed.

Curricula on Three-Year Basis

The various curricula are prepared on the basis of a three-year program of fundamental instruction designed to correlate theory with practical work. The classes meet for 120 class hours each year and successful students are awarded certificates upon completion of each year of the work and an extension diploma when they have completed the course. The work is of less than college grade and is conducted strictly on an adult vocational educational basis.

This year, because of greater latitude in federal legislation providing money for vocational instruction, the demand upon the college for educational programs in the mineral industries is greater than ever before.

Nine class centers in ceramics have been organized at Clarion, Derry, Kittanning, Lock Haven, Mount Union, New Brighton, New Castle, Summerville, and Washington.

Extension Staff Has Eight Members

In addition to the director and two stenographers, the personnel of the extension division includes D. C. Jones, supervisor of coal mining extension; E. J. Teichert, supervisor of metallurgy extension; M. M. Stephens, supervisor of petroleum and natural gas extension; E. P. McNamara, supervisor of ceramic extension; and Keith D. Pfoor, assistant supervisor of coal mining extension.

UNIVERSITY OF ILLINOIS

Ceramic Students on Annual Inspection Trip

Each year the seniors of the College of Engineering at the University of Illinois spend four days visiting various industrial plants. The purpose of the trip is to give each man a practical demonstration of the application of his theoretical studies.

The schedule followed by members of the Ceramic Department was planned by R. K. Hursh and A. I. Andrews of the Department. Arrangements were made for 32 seniors and 2 graduate students.

The students first visited the Ingram-Richardson Enameling plant at Frankfort, Ind., where they had a fine lunch in the Company cafeteria.

The Elwood, Ind., Pittsburgh Plate Glass plants were next visited. This division of Pittsburgh Plate was engaged in the production of tank blocks and other large refractories. The drying problems encountered were particularly interesting.

At Anderson, Ind., a visit was made to the National Tile Co., where the students were highly impressed with the variety of shapes, sizes, and colors produced.

The operations of a glass plant were seen at the Ball Brothers plant at Muncie, Ind. A rubber mill and the smelting and rolling operations needed for the production of zinc for Ball Brothers were also inspected there.

Visits were made to the Standard Sanitary plant at Kokomo, Ind., and to the Square D Electrical Porcelain plant at Peru, Ind.

In Chicago, the students visited the Chicago Vitreous Enamel plant in Cicero, where the students were shown the well-equipped laboratory and the careful control of production which is exercised.

The ceramic group joined the electrical engineering group from the University at the Commonwealth Edison plant. After luncheon in the Company cafeteria, the groups again separated, and the ceramists visited the Harbison-Walker Refractories plant. Although this was the last scheduled visit of the trip, a number of members took advantage of a Saturday morning trip to the Carnegie-Illinois Steel plant in South Chicago.

Student Appreciation

Once again, a senior class of University of Illinois ceramists has completed the annual inspection trip, and its members would like to join with the faculty in an expression of gratitude to those of the industry who each year extend their hospitality to the students of Illinois. Thank you very much!

—P. M. Wheeler

ILLINOIS SENIOR CLASS ANNUAL

The second annual publication by the senior class of the Ceramic Department of the University of Illinois, *The Illini Ceramist*, will be distributed in March 1938. W. R. Johnson is editor, and L. J. McCleish is business manager. Both are seniors in ceramic engineering.

The annual will be approximately forty pages. Pictures, including the senior inspection trip, views of the campus, departmental snap-shots, and of all the classes, will constitute the main portion of the annual.

The purpose of the annual is to acquaint the underclassmen with seniors and juniors in the Department and to acquaint industrialists in the various phases of the ceramic industry with the Department.

All alumni of the Ceramic Department of the University of Illinois are encouraged to write to *The Illini Ceramist* to give information as to their position, company, and location. This information will be published in the annual under the Grad News section.

—Leland J. McCleish, *Business Manager*

FORTIETH ANNUAL MEETING OF THE AMERICAN CERAMIC SOCIETY
March 27–April 2, 1938

Technical Papers

More than 135 papers have been pledged. Abstracts for many of these have been made available through press releases. Paul F. Kerr, professor of mineralogy at Columbia University, New York, N. Y., will deliver the Edward Orton, Jr., Fellow Address. One of the invited guest speakers is R. E. Grim of the Illinois Geological Survey. A. V. Bleininger, Newell, W. Va., will lead a symposium on "Properties of Glazes."

All eight Divisions have full programs arranged to be given simultaneously. Four general sessions with addresses of general interest and of basic import by authorities on their respective subjects will distinguish this Meeting from those of the last nineteen years.

Entertainment

The ladies have had planned for them the most attractive and unique series of events which are possible only in this, a most unusual and interesting city. The ladies will "get the works" intensely, happily, and with joy overflowing.

Special tour guides with intimate knowledge of all the famed and unusual places and objects have been employed. They have several optional tours from which to make selections, each planned to cover the many places of interest and varied character most thoroughly and quickly.

The entertainment at Hotel Roosevelt on Sunday night will be wholly by local talent and with local color. "Heap much fun" and entertainment, informal and without charge.

The Tulane Glee Club is scheduled to put on its best program at a place and under conditions not possible other than in New Orleans.

The attending students will have a free lunch and entertainment one evening at a place and under conditions that will make this occasion one talked about as long as those who attend will have memories and speaking abilities.

The "Keramoses" will meet, not in the bulrushes, but in a "joint." My, how envious their respective wives will be, and yet they need not greatly mind for the night will still be young when the "Moses" will return to lead the ladies to the "promised lands" of their choices.

Living Quarters

Hotels to suit every purse, fat or slim, each serving meals for a range in prices so that none need go hungry and the most fastidious epicure can have unlimited choice of dishes cooked only as they know how to do them down in New Orleans.

Profits to Be Had

Each delegate will put in more than the usual eight hours each day on ceramic subjects.

Each delegate will make new friendships and will renew and will strengthen his friendship with men and women, with whom exchanges in experiences and in opinions have enabled the most successful ceramists to make progress.

Educational Exhibits

The geological surveys have planned exhibits of ceramic materials, crude and developed, together with ceramic ware produced with them.

Economic Benefit of Meeting in New Orleans

If traveling to places where history has been made, where folks are aggressively up-to-date in commerce, in manufacturing, in education, and in the fine arts, no city on earth is a more profiting place to visit than is New Orleans.

If pushing to far corners the doctrine that ceramic products are superior to all other competing materials and the doctrine that ceramic products made in America are not inferior to any and superior to most in quality and service, it will pay you to spend the week of March 27 in New Orleans.

THE EDWARD ORTON, JR., FELLOW MEMORIAL ADDRESS
Fortieth Annual Meeting, March 27–April 2

This Address Will Be Delivered by P. F. Kerr

Paul Francis Kerr, Columbia University, New York, N. Y., was born at Hemet, Calif., January 12, 1895. He received the degree of B.S. at Occidental University in 1919, and a Ph.D. degree at Stanford University in 1923. During 1923 and 1924 he was acting instructor in Mineralogy at Stanford University and since 1924 has been located at Columbia University as instructor, assistant professor, and professor of the Department of Mineralogy.

The title of Dr. Kerr's Memorial Address and an abstract outline follow.

Subject: "A Decade of Research on the Nature of Clay"

The last decade has witnessed a great advance in knowledge of the fundamental mineralogy of clay. As the decade started, many different clay minerals, covering a wide variation in character, were thought to exist. These provided a large list of names, many of which were of doubtful validity. The progress of research throughout the decade has greatly simplified this list. The fundamental units in which clay may occur are much better known. It is now generally recognized that the more important clays are made up of comparatively few minerals with characteristics and origins that are fairly well understood. Many old names have gone into the discard. Problems concerning the mineral constituents of clays are by no means entirely solved. It seems, however, that the time has been reached when a great quantity of the fundamental information being produced in research laboratories, both in the United States and abroad, may

be turned toward specific applications. It is believed that the ground work has now been laid which will result in a period of technological research comparable to the period of fundamental research of recent years.

Paul F. Kerr

The advances of the last decade have been largely brought about by coöperative research. The problems under investigation have been such that few individual investigators have had the training or the equipment necessary for the solution of the more important problems. As a result, nearly all of the more important contributions have been the work of two or more investigators. Not only have individuals coöperated, but there has been a fine spirit of coöperation between various institutions.

A résumé of men and institutions involved in clay mineral research, recent developments in clay mineral technique, efforts made to obtain satisfactory samples for study, treatments devised for handling samples in order to secure reliable results, and studies of the conditions under which clays are found in nature, provides an interesting chronicle which should be of interest to all who are concerned with that most important of natural products—clay.

RALPH E. GRIM INVITED LECTURER

The subject of Dr. Grim's address will be "Relation of the Constitution to Properties of Clays."

Dr. Grim is Head of the Petrographic Division of the Illinois State Geological Survey, having served in this capacity beginning in 1931.

Ralph E. Grim obtained a Ph.B. degree at Yale University in 1924. For two years he remained at Yale for graduate work in petrology and economic geology. He continued his graduate work at Iowa in sedimentation and petrology, obtaining a Ph.D. at Iowa in 1931.

From 1926 to 1930, Dr. Grim was Assistant State Geologist in Mississippi, doing research on the stratigraphy, petrology, and economic geology of the formations of the Coastal Plains. During these years he also served as Assistant Professor of Geology at the University of Mississippi at Oxford.

Since joining the Illinois State Geological Survey in 1931, Dr. Grim's chief work has been on the constitution of clays and shales and on the relation between factors of constitution and physical properties. These problems he attacked mainly from the angle of petrography.

R. E. Grim

Dr. Grim is a Fellow of the Geological Society of America and of the Mineralogical Society of America and is a member of the Society of Economic Geologists.

SYMPOSIUM ON GLAZES*

ALBERT V. BLEININGER, LEADER

When we realize what amount of study and investigation has been and is being devoted to the subject of the physical properties of glasses, it is apparent that we are lamentably ignorant of glazes. It would seem, as Ross C. Purdy suggested several years ago, that a general symposium on glazes would be of much importance. This is especially true when we consider the complex systems with which we are dealing here, complicated by the constant interaction between glaze and body, which in most cases is exceedingly intensive owing to the thinness of the glass layer.

Because the number of glaze types is so great, it might be advisable to restrict the Symposium to a limited number of commercial glazes, the practical working properties of which are relatively well known. The study of the properties of the glazes should not be confined to the characteristics usually considered but should embrace all of the physical qualities that can be estimated or examined. The investigation as a whole should be as broad and basic

* Received January 5, 1938.

as possible, since only in this way could it yield adequate results.

We realize fully that much of the information desired is not available, but nevertheless a program should be mapped out which would arouse interest in the unknown factors and would incite workers to assist in filling the wide gaps in our information.

What is proposed, then, would be to start a compilation of what data are in existence and to begin coöperative efforts in the direction of accumulating the large amount of additional information required.

Attacking the subject from the purely technical standpoint, we should have knowledge concerning the following characteristics and properties of glazes:

(1) Chemical classification.
(2) Prefusion and fusion phenomena, especially with reference to vesicular structure and gas evolution.
(3) Porosity and shrinkage measurements from low temperatures to the beginning of fusion, correlated with temperature.
(4) Viscosity-temperature relation up to complete fusion.
(5) Transformation point.
(6) Softening point.
(7) Internal structure of fused glaze, with reference to immiscible layers, and number, size, and distribution of bubbles and seeds. Presence of undissolved and crystallized material.
(8) Surface texture with reference to brilliancy or matness, surface films, reflecting power, smoothness, the presence of craters, blisters, and bubbles (as shown by suitable photography). The presence of undissolved and crystallized material.
(9) Kind and degree of opacity and light transmission.
(10) Mean index of refraction.
(11) Type of post-fusion phenomena with special reference to temperature and extent of gas evolution.
(12) Color reflected as per spectrum analysis.
(13) Microstructure of boundary surface between glaze and body.
(14) Measurement of kind and degree of stress existing between glaze and body (Steger and other tests).
(15) Thermal expansion of the glaze as such and when attached to the body.
(16) Mechanical properties of the fused glaze as such, with special reference to the modulus of elasticity and resistance to tension.
(17) Effect of heat treatment of the glaze as such upon thermal expansion and irreversible volume changes.
(18) Effect of aging and storage of glaze rods under atmospheric and special conditions with special reference to volume changes and permanent set.
(19) Effect of glaze upon the mechanical properties of the body to which it is applied with reference to its mechanical strength and elongation under humid atmospheric conditions.
(20) Hardness of glaze.
(21) Resistance of glaze surface to chemical agencies.

MINERAL EXHIBIT OF ALABAMA GEOLOGICAL SURVEY

W. B. Jones

Walter B. Jones, State Geologist of Alabama, announces that the Alabama Geological Survey, University, Alabama, will exhibit a comprehensive group of Alabama ceramic minerals at the Fortieth Annual Meeting, American Ceramic Society, to be held in New Orleans the week of March 27.

The exhibit, illustrating a large proportion of Alabama's mineral resources, will feature the potential ceramic use of these materials as well as depict some of the existing uses for which they are suitable. It will be designed so as to be easily understood by the layman and in particular will appeal to the ceramists gathered in New Orleans for the Meeting.

Alabama is rich in ceramic clays and other minerals necessary to certain ceramic processes, including asbestos, barite, bauxite, cassiterite, coal, corundum, kyanite, dolomite, feldspar, fluorspar, fuller's earth, ganister, gold, graphite, gypsum, iron ores, lignite, limestone and its many products, manganese, ochre, pyrite, quartz, and talc. In addition to these are a number of extensive sand deposits which have been found particularly suitable for the manufacture of glass. Samples of all these materials will be on exhibit at the New Orleans Meeting.

Included in the exhibit will be a large map of Alabama ingeniously lighted to show locations of ceramic minerals and producers throughout the State. The location lights on this map will be synchronized with lighted samples in

the foreground to show quality of material as well as location.

Another feature of the exhibit will include a display of Alabama marble, showing the splendid luminous qualities of this material. Recent developments by Alabama marble producers and illumination experts have revealed a startling beauty when the stone is illuminated by transmitted light. Mantels and other marble trim and ornamental features are now being produced commercially, which are suitable for this type of lighting. It is expected that the exhibit will include a complete mantel and several other ornaments.

S. J. Lloyd, Dean of the School of Chemistry, Metallurgy, and Ceramics, University of Alabama

Dr. Jones announces that he will also include in the exhibit a group of fluorescent minerals collected from all over the world. These minerals will be displayed under a fluorescent light source to present a gorgeous array of color which is given off by the specimens when excited by the ultra-short invisible light rays. According to Dr. Jones these minerals, gathered from remote parts of the globe, are well worth the time spent viewing them.

Dr. Lloyd is scheduled to present a paper entitled, "Geology of the Nonmetallics of the Southeast."

GENERAL ENTERTAINMENT

Sunday, March 27

8:00 P.M.

Dinner, a la carte, Grand Ball Room, Hotel Roosevelt (11-piece orchestra will furnish music for dancing).

Entertainment during dinner to be interspersed with general dancing and get together of members. Very informal.

The entertainment will be called "Highlights of Louisiana's History," which will include the following general plan:

(1) La Salle claims "the heart of America" for King Louis XIV of France (girls dance picturing the Mississippi).
(2) Iberville and Bienville with "Naughty Marietta" (the famous brothers who founded New Orleans, present the singing "casket girl").
(3) The Louisiana Purchase Era: Settling "affairs du coeur" by swords under the famous duelling oaks in City Park.
(4) Jean Lafitte, the Pirate, with his cohorts, entertained by dancing slave girls.
(5) Andrew Jackson dancing with a Creole belle following the Battle of New Orleans.
(6) The Famous Dolly Madison Bath, a satire on Cecil B. deMille's "The Buccanneer."
(7) Louisiana's famous "Evangeline" singing to her Acadian.
(8) Sons of Louisiana Fight for the South (two tap dancers in Confederate uniforms tapping to "Dixie").
(9) Louisiana in the "Gay Nineties" (The Floradora Sextet).
(10) New Orleans, the birth place of Jazz, and the start of the original Dixieland Jazz Band (a group of five from the orchestra).
(11) A typical Vieux Carré Street Scene (little dancing niggers with their soap-box band, colored mammies selling pralines, chimney sweeps calling their unique chant, flossy ladies, "cajun dialect," etc.).
(12) The Grand Finale, "The Big Apple."

Monday, March 28

2:00 P.M.

Visit Tulane University and Newcomb College.

Lecture by Frans Blom, Museum of Middle American Research, Tulane University.

Newcomb School of Art, Newcomb College, Sixth National Ceramic Exhibition.

Newcomb Pottery.

7:00 P.M.

Dinner, Tulane Refectory.

8:15 P.M.

Concert by Tulane Glee Club, Dixon Hall.

Tuesday, March 29

8:00 P.M.

Student Reception.

Dinner, Patio Royal, 417 Royal Street.

Music for dancing and entertainment in outdoor patio in the heart of the Vieux Carré.

Entertainment will be furnished by Tulane University, Newcomb College for Women, Loyola University, Ursuline Convent, and Louisiana State University students. This will be entirely collegiate entertainment for visiting students.

Wednesday, March 30

8:00 P.M.

President's Reception, Hotel Roosevelt.

Edward Orton, Jr., Memorial Lecture, by Paul F. Kerr, Columbia University, New York, N. Y.

HOTEL RATES IN NEW ORLEANS

De Soto

Singles with bath	$3.00, 4.00, 5.00
Doubles " "	5.00, 6.00
Twin beds " "	6.00, 7.00, 8.00

Jung

Singles with bath	$3.00, 3.50, 4.00, 5.00
Doubles " "	5.00, 6.00, 7.00
Twin beds " "	6.00, 7.00, 8.00

La Salle

Doubles with bath	$4.00, 5.00
Twin beds " "	5.00, 6.00

Monteleone

Singles with bath	$3.00, 4.00
Doubles " "	5.00, 6.00, 7.00
Twin beds " "	6.00, 7.00, 8.00

New Orleans*

Singles with bath	$3.00, 4.00, 5.00
Doubles " "	5.00, 6.00
Twin beds " "	6.00, 7.00

Pontchartrain

Apartments to accommodate 2 persons	$8.00 per day
" " " 4 "	15.00 " "

Roosevelt

Singles with bath	$3.50, 4.00, 5.00, 6.00
Doubles " "	5.50, 6.00, 7.00, 8.00
Twin beds " "	7.00, 8.00, 9.00

St. Charles

Singles with bath	$3.00, 3.50, 4.00, 4.50, 5.00
Doubles " "	5.00, 5.50, 6.00, 6.50, 7.00
Twin beds " "	6.00, 7.00, 8.00

* Commercial hotel: Not more than 40 or 50 rooms available for Meeting guests.

RAIL FARES TO NEW ORLEANS

Southwestern carriers have established low round-trip first-class excursion fares to New Orleans, La., which are in effect daily and which grant liberal return limits. The thirty-day limit fares on the basis of $2^1/_4$ cents per mile in each direction offer a reduction comparable with that authorized for conventions prior to the general reduction in railroad passenger rates. Tickets are good for travel in sleeping and parlor cars upon payment of the usual charges for accommodations furnished.

In addition, those desiring to travel in coaches and chair cars only may avail themselves of the round-trip coach fares on a still lower basis.

In view of the substantial reduction offered by these round-trip fares and the fact that tickets may be obtained without presenting credentials or obtaining a receipt certificate entitling passenger to reduction on the return trip, special reduced fares for conventions have been discontinued.

We feel confident that the liberal arrangements outlined above will attract a large attendance by rail from southwestern territory.

—W. J. Rodgers
Chairman, Southwestern Passenger Assn., St. Louis, Mo.

Southeastern carriers have in effect daily reduced round-trip fares on the basis of $2^1/_4$ cents per mile in each direction for tickets bearing limit of 15 days in addition to date of sale going and returning the same route.

Daily round-trip fares on the basis of $2^1/_2$ cents per mile in each direction for tickets bearing limit of six months in addition to date of sale are also in effect going and returning the same route; also via diverse routes on the basis of one-half of the round-trip fare constructed as above via route used on going trip, plus one-half of the round-trip fare constructed as above via route used on return trip, *except* that no diverse routes will apply in Florida south of Jacksonville or between the A.C.L.R.R. and S.A.L. Railway through the Virginia gateways.

Tickets will be honored in sleeping or parlor cars upon payment of sleeping or parlor charges.

Round-trip tickets, good in coaches only on the basis of the lower one-way coach fare of 2 cents per mile with a limit of 30 days in addition to date of sale, will also be available.

The carriers have decided that *no other reduced fares* will be authorized for occasions held in the Southeast. It will be noted that the 15-day limit fare and also the coach fare are on approximately the same basis as the former convention basis of one and one-third fare rate.

Members of the American Ceramic Society in this territory are hereby notified of the foregoing daily reduced round-trip fares so that they may be availed of in connection with this Meeting.

—C. B. Rhodes
Southeastern Passenger Assn., Atlanta Ga.

Orleans Street, New Orleans

COMMUNICATIONS—CERAMIC HISTORY

EDWARD DRUMMOND LIBBEY

Edward Drummond Libbey, glass manufacturer, philanthropist, patron of art, was born April 17, 1854, at Chelsea, Mass., the son of William L. and Julia (Miller) Libbey. He received his education in Boston and later attended lectures at Boston University. In 1874, he entered the factory of the New England Glass Company, East Cambridge, Mass., of which Company his father was general manager, and worked in all of its branches to learn every detail in the manufacture and marketing of glass. In 1883, upon the death of his father, who had bought the business some years before, he become sole proprietor. In 1886, a strike by the workmen for higher wages, which conditions could not justify, made it necessary to close the plant permanently.

Attracted by the ample supply of natural gas and good glass sand, Libbey then went to Toledo, Ohio, and in 1888 began operations there under the name of the Libbey Glass Company. In 1893 he erected a building at the World's Columbian Exposition, Chicago, Ill., in which he operated a demonstration glass plant throughout the period of the Fair. Becoming interested in the development of automatic machinery for the manufacture of table tumblers, the invention of Michael J. Owens, he organized the Toledo Glass Company in 1894, and in the plant which was constructed for it carried on the manufacture of table tumblers until 1899, when the plant was acquired by the American Lamp Chimney Company, of which Libbey was president. This company was soon consolidated with the Macbeth-Evans Glass Company of Pittsburgh, Pa., and the Toledo plant was operated as a branch factory.

In 1899 Owens developed a machine for blowing bottles, perhaps the most revolutionary contribution to the glass industry since the invention of the blowing iron. In 1903, the machine having been perfected, Libbey organized and became president of the Owens Bottle Machine Company (reorganized in 1919 as the Owens Bottle Company), which took an exclusive license from the Toledo Glass Company for the manufacture in the United States of the bottle machine and all kinds of bottles. The Owens European Bottle Machine Company was organized in 1905. In 1912 Libbey purchased for the Toledo Glass Company the Colburn patents for the manufacture of sheet glass, and after the process had been further developed by Owens and the original inventor, he organized and became president in 1916 of the Libbey-Owens Sheet Glass Company, which purchased these patents and embarked upon the manufacture of sheet and plate glass at Charleston, W. Va.

Libbey was intensely interested in civic, philanthropic, and educational work. He served on the Toledo Board of Education, and, as its president, began a notable building program. For many years he supplied scholarships through which the teachers of the public schools could continue their higher education, and by his will provided for the perpetual maintenance of a scholarship fund. He was also a member of the City Plan Commission. In company with other citizens, he organized, in 1901, the Toledo Museum of Art, of which he was president until his death. In his first annual report, 1902, he advocated a policy of education as well as conservation, foreseeing for the institution a future in which it should take its place as an educational factor along with the public schools, colleges, and universities. He made possible the erection of the first unit of the Museum building, opened in 1912, and later gave an addition, dedicated in 1926, which more than doubled its size. He made frequent trips abroad and with his wife Florence (Scott) Libbey, whom he had married in 1890, formed a collection of paintings, including works of Holbein, Hals, Rembrandt, Velasquez, DeHoogh, Van Cleef, Reynolds, Gainsborough, and Raeburn, which he gave to the Toledo Museum. He also presented to the Museum a collection of Egyptian antiquities and a unique collection of glass, and by bequest left it the bulk of his estate, providing funds for additions to its building, for the maintenance and operation of the Museum and its educational program, and for the acquisition of works of art for its permanent collections. In 1922, in recognition of his services to industry, commerce, and art, King Albert conferred upon him the Belgian Order of the Crown with the rank of Commander.

Mr. Libbey died November 13, 1925.

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SPODUMENE IN NORTH CAROLINA

Millions of tons of a hitherto rare mineral which contains the lightest metal known, so light that it will float on water and is five times lighter than aluminum, have been located in North Carolina. The mineral is known as "spodumene," and from this is produced lithium, the feather-weight metal, with a soft silvery-white color. It is used as an alloy to harden such metals as aluminum and lead and in the manufacture of lithium-chloride salt, now being extensively used in certain types of air-conditioning equipment. Lithium is also in demand for use in some types of storage batteries.

Until this tremendous deposit of spodumene was discovered in North Carolina in 1936 by Frank Hess, geologist with the U. S. Bureau of Mines, virtually the only

other known deposits were in the Black Hills of North and South Dakota, and these deposits were very limited, according to Herman J. Bryson, North Carolina State Geologist and chief of the mineral resources division of the Department of Conservation and Development.

A furnace has been built on the property to separate the spodumene from other minerals found in the rock formations by the calcining method. When lumps of the mineral are heated to a high temperature, the matter in the ore remains in large lumps above the screen. It is thus possible to obtain almost 100% pure spodumene at the site of the mine before any is shipped. No attempt has been made so far to process the spodumene and to derive lithium from it in North Carolina, although several companies are known to be interested in acquiring some of these spodumene deposits and in erecting complete processing plants.

At present, the development of this deposit is being carried on in a limited manner. Geologists and industrial engineers predict that the presence of this mineral in such large quantities should bring about the development of another large mineral industry in the State. North Carolina is already recognized as one of the largest producers of kaolin and feldspar in the world.

THE EDWARD ORTON, JR., CERAMIC FOUNDATION

On February 10, six years ago, our Edward Orton, Jr., passed away. For more than twenty years he had been our Professor. That concurrently he had served as Dean of the College of Engineering and as Director of the Engineering Experiment Station at Ohio State University did not change with us his status of Professor. That for several of those twenty years he served Ohio as Director of the State Geological Survey, making surveys, writing reports, and directing the work of others did not change with us his status of Professor. As though his duties as Professor, Dean, and Geologist were not enough to exhaust his energy and to overextend his capabilities, he served during those same twenty years as Secretary and Editor of the American Ceramic Society, and a right thorough job he did in each of these tasks, all of them without financial compensation other than that of his salary as a Professor, which salary was graduated during those years from $1200 to $3600 per year.

Still his status with us was as Professor.

Truly did Edward Orton, Jr., work from 1895 to 1915, his professorial years, with a devoted singleness of purpose for the ceramic industries of America.

The world war made a change in his services. Always in love with things military, Professor Orton could not stay home. He went into training at Plattsburg, N. Y., and then served in various capacities during the years the United States was in the war. He was discharged with the rank of Lieutenant Colonel, almost immediately was given a Distinguished Service Medal, and later the rank of Brigadier General.

Truly did our Professor, now General, serve his country with a devoted singleness of purpose.

Now he was our General Orton.

With his war service terminated, he returned to Columbus. He refused academic offers. He accepted, without pay, an Emeritus Research Professorship at Ohio State University.

The next ten or twelve years brought Edward Orton

Edward Orton, Jr., Ceramic Foundation Personnel (2 absent)

Jr., into many civic and charity jobs, always as a leader, organizer, and builder. Columbus and her citizens have much in public buildings, grade-crossings, boulevards, and guild houses, planned and many of them built under his direction, all done without compensation and some of it financed by him.

Truly did our Edward Orton, Jr., give ten or more of his years unstintingly to his home city.

From 1895 to 1932, our Edward Orton, Jr., was rendering another unselfish service, this alone to the ceramic industries. He made and marketed standard pyrometric cones, at first at a financial loss until American ceramists learned why and how to use them. The business grew to such a proportion that he could no longer have on the Ohio State University Campus the room required to stock his raw materials and finished cones or to test and make the cones. Although the cone business did not yet warrant the outlay, he financed the construction of a "factory" close to the University. When our Edward Orton, Jr., was discharged from the army service, his cone business was his sole source of income and a meager income it was.

Hand Molding Room, Edward Orton, Jr., Ceramic Foundation Standard Pyrometric Cone Plant

In the adjustment of estates of his relatives, he bought off claimants and, in the final write-off, he found himself possessed of two farms. He became a farmer but as a pastime, as a man plays golf.

As the following table shows, his Standard Pyrometric Cone business improved rapidly and in a substantial amount beginning in 1920. Unselfishly devoted, he again invested his all for others. He conceived and wrote into his last testament and will his plans for a Ceramic Research Foundation. Again into the bank he went, mortgaging his High Street factory and the new laboratories so he could spend more than $100,000 in a research laboratory which, on his passing, would belong to and be operated without profit by the ceramic industries through services rendered.

CONE SALES FROM 1920 THROUGH 1937

1920	3,279,698	1926	7,545,993	1932	3,549,965
1921	2,771,786	1927	7,594,998	1933	4,382,727
1922	3,832,665	1928	8,537,690	1934	4,410,279
1923	5,169,500	1929	9,559,858	1935	4,888,749
1924	6,660,303	1930	7,900,549	1936	5,358,105
1925	6,374,761	1931	6,228,136	1937	6,061,897

Illness and business depression came upon our Edward Orton, Jr., before he could complete the several public service enterprises which he had planned.

His Godman Guild enterprises were nearly complete, one part of which was a $30,000 camp home on the Olentangy River, named Camp Mary Anderson Orton in memory of his first wife.

His Geological Library at the University, costing another $30,000, was completed. This he gave as a memorial to his father. He endowed this with a $10,000 insurance which assures the library an annual income of $600.

The civic projects initiated with him while President of the Chamber of Commerce are just now being completed, the last being the boulevard running north on the west side of the Olentangy River.

The Columbus Gallery of Fine Art which was planned, financed, and built while he served as treasurer is completed. It is a magnificent monument to his devoted service to others.

The Community Fund which he served from its beginning has continued in the same high level to which he brought it. The generosity of and the thorough work rendered by our Edward Orton, Jr., is told of annually.

The Archaeological and Historical Society of Ohio of which he was a Vice-President completed two large wings while he served as Chairman of its Building Committee. Here is another grand monument to the unselfish public service of our Edward Orton, Jr.

It was to the Edward Orton, Jr., Ceramic Foundation that he devoted most of his time, thought, and plans. It alone, of his many public enterprises, was definitely and in detail, planned in his last will and testament. Had he not passed away just as the depression came on, he would have carried his cone business through to full solvency. His illness for several months, together with the low income, brought on a financial situation on account of which the court, had his wife so requested, would have set aside those provisions in his will by which he gave away her only source of income, the Standard Pyrometric Cone Company. Imbued with the public-service spirit and determination of our Edward Orton, Jr., she, as one of the executors, helped work out a plan by which the business could be taken over under Trusteeship. Thus all of the many obligations and pledges were assumed as liabilities by the Trustees under agreement with the court.

The Trustees are glad to report that not only has the income been sufficient to pay annually to Mrs. Orton the sum specified by Edward Orton, Jr., but it has been sufficient to pay off all but $11,100 of the indebtedness. United States bonds totalling $13,601.43 have been purchased to meet depression emergencies and the $11,100 indebtedness is a $3^1/_2\%$ federal loan. The Trustees of the Foundation can report therefore that, through the continued and increased purchases of cones, the Foundation is now wholly solvent.

Achieving financial solvency is not all that the Foundation has done in these six years since our Edward Orton, Jr., passed from us. It has made decided improvements in the cones and has invested in researches through fellowships at universities. Four such fellowships are now in force, one each at Ohio State University, Pennsylvania State College, Rutgers University, and the University of Illinois. As means permit, more such fellowships will be financed.

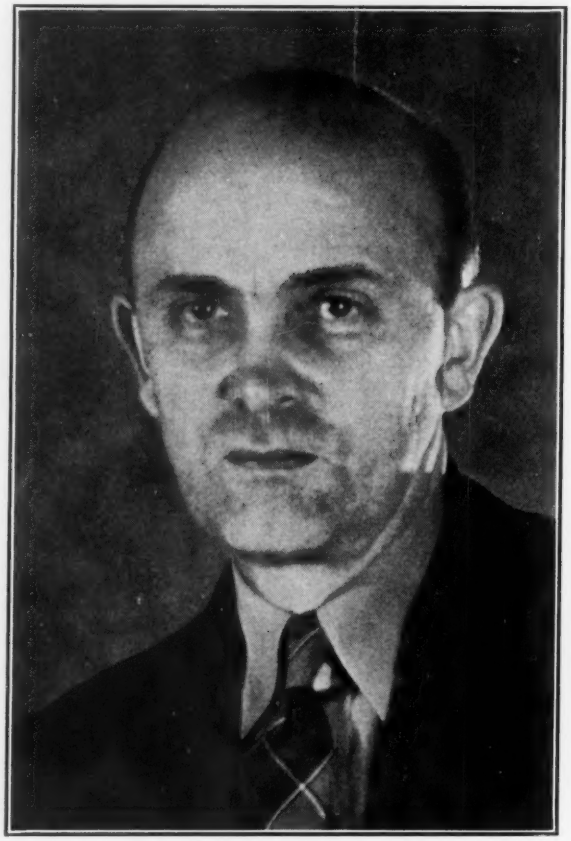
The Foundation has done more than attain solvency and establish fellowships. Consistent with the policy of Edward Orton, Jr., of making cones available at the lowest possible cost, the basic sale price of the cones was first reduced from $13.00 to $11.00 per thousand cones, and beginning with January 1, 1938, quantity discounts have been scheduled on the basis that the production and distribution costs are lowered as the number of cones sold increases.

While thus serving the ceramic industries through research fellowships, lower sale prices, and achieving financial solvency, the Foundation has accomplished a much more important service to the ceramic industries by improving the quality of the cones and developing methods that assure greater uniformity. New equipment has been installed. New production methods are being developed. New compositions have been thoroughly tested and brought to standard. All of these things have been done to correct the many faults which cones of the past have had.

The Foundation has made yet another investment in the interest of the ceramic industries. It has secured the services of Duane F. Albery to work with Messrs. Bole, Shaw, and CoVan on development and control. Every one of the staff shown in the group picture should be listed as ardent control scouts for perfection in performance of the cones is their ambition. They know that cone reliability is dependent on the integrity molded into the cones by each person employed in their production.

Duane F. Albery was born in Columbus on December 3, 1887. He went to the public and high schools in Columbus and to Ohio State University, receiving a Ceramic Engineer degree in 1909. His industrial experiences cover (1) three years with the American Terra Cotta and Ceramic Company, (2) two years operating his own pottery, (3) five years with the Federal Terra Cotta Company, (4) one year with the General Electric Company, (5) sixteen years with the Northwestern Terra Cotta Company, and (6) one year again with the American Terra Cotta Company.

"Buz," as he is widely known, has served the American Ceramic Society for more than twenty years in various capacities; for one term of three years as Trustee. He has contributed to ceramic literature. As superintendent of the Northwestern Terra Cotta Company he modernized its methods and equipment. He developed its body and glaze compositions to meet every competition. "Buz" knows ceramics. He knows the importance of securing and of maintaining the highest possible accuracy through process and composition control.



D. F. Albery

Duane F. Albery is a valuable addition to the staff of the Edward Orton, Jr., Ceramic Foundation.

Six years! What the Foundation will accomplish in public service, as Edward Orton, Jr., willed it to do, during the next six years will depend largely upon the staff and upon the continued patronage of the ceramic industries for whom in trusteeship the Foundation is operated.

THE BEGINNINGS OF WHITE TABLEWARE*

By Harold Edison Stewart

At the opening of the Seventeenth Century, England's potteries were turning out more or less crude earthenware, in the form of jugs, jars, crocks, and the like. An important center of the English industry was the group of potteries located in and about Stoke-on-Trent and Burslem in Staffordshire. Better ware came into the country from abroad. Large quantities of Delftware were imported, entering principally through the eastern ports. "Traffic between . . . . . (Yarmouth) and Holland was immense; and almost every trading vessel brought a portion of Dutch earthenware."[1] Through immigrant Dutch potters, Delftware manufacture was introduced into England around 1630, but seems to have made little headway before 1700. Tea drinking came into popularity in England in 1703 with Queen Anne, and with it new life in English potting. The production of Delftware gradually increased. The Elers brothers, immigrant Dutch potters settling near Staffordshire, in 1710 began to produce finely formed and daintily decorated stoneware teapots from the local clays, whose beauty and ready sale stimulated imitation among the Staffordshire butter-pot makers and really initiated the

* Taken from dissertation presented in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, Ohio State University, December, 1937.

[1] E. Meteyard, Life and Works of Wedgwood, Vol. 1, p. 110 (1865).

movement which was to make Staffordshire pottery famous throughout the world.[2]

The British potters, at last awake, adopted during the first half of the eighteenth century several improvements in technique that had been evolved in foreign countries, and themselves inaugurated a series of developments which were to revolutionize the pottery industry there and abroad. Improvements were made in the use of molds, in the design of the potter's wheel, and in other processes. Astbury, in 1720, discovered the use of flint in the body to give it hardness and whiteness, and so led to the production of fine stoneware. In 1750, Enoch Booth introduced a transparent lead glaze, and the Continental method of two fires of ware, in the first of which the ware was fired to a biscuit state, then decorated and dipped in glaze and fired a second time. Booth produced, in 1750, a smooth cream ware which Wedgwood was to improve and make immortal. The decoration of ware by the process of transfer printing, which was begun in 1755, was a discovery of the greatest importance, since it made possible decorated ware at low cost and provided a very flexible medium for the application of a wide variety of decorative motifs. "It was the first opportunity common folk had of getting a decorated plate to eat off."[3] All this culminated about 1760, with the introduction by Wedgwood of his improved cream-colored ware, a ware of real beauty, with a body composed of a mixture of clays, feldspar, and flint. In 1762 he secured an order from Queen Charlotte for a complete dinner service of the new ware, was permitted to use the title, "Potter to Her Majesty," and in grateful recognition called his new product, "Queensware."

The stamp of royal approval inaugurated the use of clay dinnerware for all table purposes. Wedgwood was deluged with orders, and other Staffordshire potters, always quick imitators, turned their energies and abilities to the new ware. Soon the manufacture of Queensware dominated the English potting industry.

A large export trade quickly developed. According to Meteyard, in 1762, "Vast quantities of ware were now exported from London, Bristol, Liverpool, Hull, and other seaports, to America, the West Indies, and almost every part of Europe."[4] The greater part of the English ware was produced, indeed, for export purposes, a fact testified to by Wedgwood in a letter written around 1765, when he says, "The bulk of our particular manufactures are you know exported to foreign markets, for our home consumption is trifling in comparison, to which is sent abroad; and the principal of these markets are the Continent & Islands of North America."[5]

This early trade was to continue, and to grow, offering competition in this, as in other trades, to the fledgling industries of the New World.

Queensware, although not strictly white, may be considered the first real whiteware. As time went on, the Queensware was gradually improved, better clays, more experience, and the addition of a small amount of cobalt causing the creamy tint to disappear and give place to white. The whiteware of today differs chiefly from the Queensware in the varying proportions and better quality of clays and other materials used and in a harder firing.

Staffordshire has remained the center of British whiteware manufacture. This is largely a consequence of the early start of the new industry in that area and the resultant concentration of skilled labor; in addition, local coal mines supply fuel and the location enables the ready assembly of the necessary raw materials and provides good access both to foreign and domestic markets.

It is to be noted that American clays played an important rôle in the early English Queensware industry. Made aware by their own experiments, as well as by the Continental developments, of the importance and function of kaolin and other white-firing clays, and not finding such suitable materials at home, the English potters extended the search to the New World. It is possible that friends and relatives going to the colonies were importuned to be on the lookout for "china clays" and many boxes and kegs of white American clays that might prove suitable must have been shipped to England. Thus, about 1744, a patent taken out by two Bow (England) potters for the manufacture of porcelain describes one of the ingredients as "an earth, the product of the Cherokee Nation in America, called by the natives, 'unaker.'"[6] This clay probably came from the Great Smoky Mountain district of North Carolina, a source of kaolin for pottery purposes today, for it is recorded that in 1755 a box of "porcelain-earth from the internal parts of the Cherokee Nation, four hundred miles from hence (Charleston) on mountains scarcely accessible," was consigned to Richard Champion, founder of the Bristol China Works, by his brother-in-law, Caleb Lloyd of Charleston, to be forwarded to the Worcester china works for experiment.[7]

In many of the experiments which preceded the famous Queensware manufacture, Wedgwood was said to have used American clays, and American clay formed part of the body of the famous Queensware itself.[8] In fact, the English Queensware and porcelain potteries were apparently dependent upon American clays prior to 1768. Although the South Carolina clays were the earliest used, as noted before, the Georgia kaolins were known at least by 1764,[9] and Wedgwood imported clay from the Pensacola, Florida, district in 1766, and from the Ayoree, Florida, district in 1767.[10] By (1767), American clays were being sent to Eng-

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[2] The formula and methods of the Elers brothers are said to have been secured by Jos. Twyford and Wm. Astbury, young Staffordshire potters who, by posing as half-witted dullards, were able to obtain work with the Dutch potters and so discover their secrets. W. P. Jervis, A Pottery Primer, p. 85 (1911).

[3] J. C. Wedgwood, Staffordshire Pottery and Its History, p. 132 (1913).

[4] E. Meteyard, *loc. cit.*, p. 154.

[5] *Ibid.*, p. 367. The extent of the demand for the ware and its effect on the Staffordshire industry is attested by Wedgwood's testimony, in 1795, that upward to 15,000 persons were then directly employed in this manufacture and double that number in auxiliary occupations in connection with the industry preparing clay, flint, coals, and other materials required by the potter. U. S. Bureau of Foreign and Domestic Commerce, The Pottery Industry, p. 390.

[6] C. W. Elliott, Pottery and Porcelain, p. 84 (1878).

[7] C. W. Elliott, *op. cit.*, p. 85. See also E. A. Barber, Pottery and Porcelain of the United States, p. 60 (1893).

[8] E. A. Barber, *op. cit.*, pp. 59, 62, 63; see also J. Spargo, Early American Pottery and China, pp. 65–66 (1904).

[9] C. W. Elliott, *op. cit.*, p. 86.

[10] *Ibid.*, p. 88; see also E. A. Barber, *op. cit.*, pp. 62–63.

and in considerable quantities,[11] but in 1768 Cookworthy discovered the excellent kaolin deposits of Cornwall, and thus ended the necessity of English potters going abroad for this material.

WAYNE UNIVERSITY
DETROIT, MICHIGAN

[11] "The Sedimentary Kaolins of the Coastal Plain of Georgia," *Geol. Surv. of Ga. Bull.*, No. 44, p. 1.

POSSIBLE EXPLANATION FOR THE OCCURRENCE OF ROLLED PEBBLES IN CLAY AND BAUXITE DEPOSITS

In various clay deposits in the United States, there occurs round and elongated clay pebbles in the matrix of clay. Sometimes these clay pebbles constitute almost the entire bed and at other times they occur sparingly. They are especially predominant in the bauxite beds of south Georgia but occur elsewhere both in the Tertiary and Cretaceous formations in the Mississippi Valley and in Texas, New Jersey, California, Minnesota, and elsewhere.

Numerous ideas have been advanced to explain their occurrence. In recent experiments carried on at the writers' plant, these clay pebbles have been synthetically produced, ranging in size from a small pea to pebbles as large as a hen's egg.

Round pebbles may be produced artificially by rolling in a drum or barrel but, in the case of the present experiments, the endeavor was purely of a scientific nature to endeavor to produce a product approaching the size and shape of the pebbles found in nature which generally are not round but elongated.

Contrary to the general belief that a rolling motion would produce the pebbles as in a barrel or drum, the pebbles produced by the writer were obtained on a flat surface having a reciprocatory motion and approaching as nearly as possible wave motion.

The writer has long held that the presence of pebbles in clay deposits could not be accounted for entirely by localized upward movement of water, such as springs, etc., owing to the fact that the occurrence of the pebbles is too great in extent laterally in the beds and too uniformly laid down and also that no evidence can be produced to show the presence of springs of an areal nature in or around such deposits.

Apparently the pebbles were produced from clay in a clayey menstrum on a nearly flat inclined plane or practically flat beach, either marine or fresh, on which water moved rhythmically. The size of the pebbles varies in ratio to the force of the movement of the water and the direction of the water, nearly at right angles to the inclined beach plane.

This inclined beach could be a considerable distance off shore where water shallow enough to be affected either by tide or surface disturbance would be found. The pebbles are produced mechanically by being gently rolled to and fro by the aqueous medium, and they start from a nuclei of either a hard pellet of clay or other material to which the clay would be attached. The size of the pebble is controlled by the movement of the water for that particular time.

Synthetically the following has been done.

On to the end of a vibrating table about 15 feet long and slightly inclined, a fine stream of an extraordinary plastic clay (ground) was fed with a stream of water. Immediately some of the clay went into solution, as it washed from the table; some dampened lumps harder than the rest of the ground clay acted as a nuclei and began to roll. Soon these pellets became elongated, ranging from the size of a pinhead to those as large as marbles. They did not dissolve in the stream of water but continued to roll and pass to the discharge of the table into a box where fine clay in solution was also discharged. This process was carried on for several hours with modifications until the box at the discharge end was filled. This box was allowed to settle and the clear water was siphoned off. After this clay in the box was dried, it was found to be composed of dried suspended clay throughout, which contained the clay pebbles. These clay pebbles, ranged in size according to the modifications of the wash water on the table at the time the experiment was being performed.

The clay used in the experiment was a pure grade, known as Klingenburg, with very little fine sand.

Cross-sections of the clay in the box, after drying, were no different in appearance from the pebbly clay at Andersonville, Ga., and Mexia, Tex., some of the flint clay beds near Belle, Mo., a peculiar bed at Alberhill, Calif., and others at Lincoln, Calif., at Enid, Miss., and Anna, Ill. Practically all of these beds belong to late Cretaceous or early Tertiary, geologically speaking.

While the production of the clay pellets and pebbles was academic in its nature in our laboratory, it sheds some light on what the possible conditions were geologically at the time the clay beds were laid down and something about the nature of the currents of water and their direction of impact on the beds along the shore.

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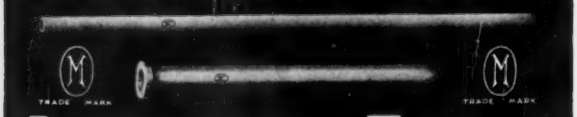
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